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TRANSACTIONS

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

VOLUME II.

Second Meeting, New York, N. Y., 1906
December 3 and 4

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DEPARTMENT OF ENGINEERING.

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Incorporated under the Laws of the State of New York,
August 30, 1905.

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OFFICERS

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

1906–1907.

PRESIDENT.

D. S. JACOBUS.....New York, N. Y.

VICE-PRESIDENTS.

JOHN E. STARR.....New York, N. Y.

Term expired at Annual Meeting of 1907.

JAMES WILLS.....New York, N. Y.

Term expires at Annual Meeting of 1908.

DIRECTORS.

THOMAS SHIPLEY.....York, Pa.
HENRY TORRANCE, JR.....New York, N. Y.
L. HOWARD JENKS.....New York, N. Y.

Terms expired at Annual Meeting of 1907.

LOUIS BLOCK.....New York, N. Y.
EDGAR PENNEY.....Newburgh, N. Y.
H. B. ROELKER.....New York, N. Y.

Terms expire at Annual Meeting of 1908.

J. J. DE KINDER.....Philadelphia, Pa.
F. W. PILSBRY.....Chicago, Ill.
LLEWELLYN WILLIAMS.....Boston, Mass.

Terms expire at Annual Meeting of 1909.

TREASURER.

WALTER C. REID.....New York, N. Y.

SECRETARY.

WILLIAM H. ROSS.....New York, N. Y.

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OFFICERS

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

1905–1906.

PRESIDENT.

W. Everett Parsons.....New York, N. Y.

VICE-PRESIDENTS.

P. D. C. Ball.....St. Louis, Mo.
Term expired at Annual Meeting of 1906.

John E. Starr.....New York, N. Y.
Term expired at Annual Meeting of 1907.

DIRECTORS.

Ellis L. Phillips.....New York, N. Y.
D. S. Jacobus.....Hoboken, N. J.
W. T. Robinson.....Philadelphia, Pa.
Terms expired at Annual Meeting of 1906.

Henry Torrance, Jr.....New York, N. Y.
Thomas Shipley.....York, Pa.
L. Howard Jenks.....New York, N. Y.
Terms expired at Annual Meeting of 1907.

Louis Block.....New York, N. Y.
Edgar Penney.....Newburgh, N. Y.
H. B. Roelker.....New York, N. Y.
Terms expire at Annual Meeting of 1908.

TREASURER.

Walter C. Reid.....New York, N. Y.

SECRETARY.

William H. Ross.....New York, N. Y.

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OFFICERS

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

1904–1905.

PRESIDENT.

JOHN E. STARR.....New York, N. Y.

VICE-PRESIDENTS.

H. B. ROELKER.....New York, N. Y.

Term expired at Annual Meeting of 1905.

P. D. C. BALL.....St. Louis, Mo.

Term expired at Annual Meeting of 1906.

DIRECTORS.

LOUIS BLOCK.....New York, N. Y.
W. EVERETT PARSONS.....New York, N. Y.
EDGAR PENNEY.....Newburgh, N. Y.

Terms expired at Annual Meeting of 1905.

ELLIS L. PHILLIPS.....New York, N. Y.
D. S. JACOBUS.....Hoboken, N. J.
W. T. ROBINSON.....Philadelphia, Pa.

Terms expired at Annual Meeting of 1906.

HENRY TORRANCE, JR.....New York, N. Y.
THOMAS SHIPLEY.....York, Pa.
L. HOWARD JENKS.....New York, N. Y.

Terms expired at Annual Meeting of 1907.

TREASURER.

WALTER C. REID.....New York, N. Y.

SECRETARY.

WILLIAM H. ROSS.....New York, N. Y.

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THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

CONSTITUTION.

NAME, OBJECT AND GOVERNMENT.

C 1. The title of this Society shall be "The American Society of Refrigerating Engineers."

C 2. The object of this Society is to promote the Arts and Sciences connected with Refrigerating Engineering.

C 3. The principal means for this purpose shall be the holding of meetings for the reading and discussion of appropriate papers, and for social intercourse; the publication and distribution of its papers and discussions; and the maintenance of a library of data on refrigeration.

C 4. The Society shall be governed by this Constitution, and by By-Laws and Rules in harmony therewith.

C 5. The Society shall be organized as a Corporation under the laws of the State of New York.

MEMBERSHIP.

C 6. Persons connected with the Arts and Sciences relating to Refrigerating Engineering may be eligible for admission into the Society.

C 7. The membership of the Society shall consist of Members, Associates and Juniors. Members and Associates are entitled to vote and to hold office. Juniors shall not be entitled to vote nor to be officers of the Society, but shall be entitled to the other privileges of membership.

C 8. Members and Associates are entitled to vote on all questions before any meeting of the Society, in person or by proxy, given to a voting member in writing. A proxy shall not be valid for a greater time than six months.

C 9. A Member shall be twenty-six years of age or over. He must have been so connected with Refrigerating Engineering as to be competent as a designer or as a constructor, to take responsible charge of work in his branch of Refrigerating Engineering, or he

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must have served as a teacher of Refrigerating Engineering for more than five years.

C 10. An Associate shall be twenty-six years of age or over and shall be so connected with Refrigerating Engineering as to be competent to take charge of engineering work, or to co-operate with Refrigerating Engineers.

C 11. A Junior shall be twenty-one years of age or over. He must have had such Refrigerating Engineering experience as will enable him to fill a responsible subordinate position in Refrigerating Engineering work, or he must be a graduate of an engineering school.

C 12. The rights and privileges of every Member, Associate and Junior shall be personal to himself, and shall not be transferable or transmissible by his own act or by operation of law.

ADMISSION.

C 13. All applications for membership as Member, Associate or Junior shall be presented to the Council, which shall consider and act upon each application, assigning each approved applicant to the classification to which, in the judgment of the Council, he is entitled. The name of each candidate thus approved by the Council shall, unless objection is made by the applicant, be submitted to the voting membership for election by means of a letter ballot.

C 14. Associates or Juniors desiring to change their grade of membership shall make application to the Council in the same manner as is required in the case of a new applicant.

C 15. Election to membership shall be by a sealed letter ballot as the By-Laws shall provide. Adverse votes to the number of four per cent. of the votes cast shall be required to defeat the election of an applicant.

C 16. Each person elected shall subscribe to this Constitution, and shall pay the initiation fee before he can be entitled to the rights and privileges of membership. If such person does not comply with these requirements within six months after notice of his election he will be deemed to have declined election. The Council may, thereupon, declare his election void.

INITIATION FEES AND DUES.

C 17. The initiation fee for membership shall be as follows:
For Members and Associates, five dollars.
For Juniors, five dollars.

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A Junior on promotion to any other grade of membership shall pay an additional fee of five dollars.

The annual dues for membership shall be as follows:

For Members and Associates, ten dollars.

For Juniors, five dollars, for the first six years of their membership, and thereafter the same as for a Member or Associate.

SUSPENSIONS AND EXPULSIONS.

C 18. Any Member, Associate or Junior who shall leave his annual dues unpaid for two years shall, at the discretion of the Council, have his name stricken from the roll of membership and shall cease to have any further rights of membership.

C 19. The Council may refuse to receive the dues of any Member, Associate or Junior who shall have been adjudged by the Council to have violated the Constitution or By-Laws of the Society, or who, in the opinion of the Council, expressed by a two-thirds vote of the entire Council, shall have been guilty of conduct rendering him unfit to continue in its membership; and the Council may expel such person and remove his name from the list of members.

THE COUNCIL.

C 20. The affairs of the Society shall be managed by a Board of Directors chosen from among its Members and Associates, which shall be styled "The Council." The Council shall consist of the President of the Society, who shall be presiding officer; the two Vice-Presidents, Treasurer and nine Members or Associates. Seven Members of the Council shall constitute a quorum for the transaction of business. The Secretary may take part in the deliberations of the Council, but shall not have a vote therein.

C 21. The Council thus constituted shall regulate its own proceedings and shall be the legal Trustee of the Society. All gifts or bequests not designated for a specific purpose shall be invested by the Council and only the income therefrom may be used for current expenses.

C 22. Should a vacancy occur in the Council, or in any elective office except the presidency, through death, resignation or other cause, the Council may elect a Member or Associate to fill the vacancy until the next annual election.

C 23. The Council shall present at the Annual Meeting of the Society a report verified by the President or Treasurer or by a majority of the members of the Council, showing the whole amount

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of real and personal property owned by the Society, where located, and where and how invested, and the amount and nature of the property acquired during the year immediately preceding the date of the report, and the manner of the acquisition; the amount applied, appropriated or expended during the year immediately preceding such date, and the purposes, objects or persons to or for which such applications, appropriations or expenditures have been made; also the names and places of residence of the persons who have been admitted to membership in the Society during the last year, which report shall be filed with the records of the Society, and an abstract thereof shall be entered in the minutes of the proceedings of the Annual Meeting.

C 24. An act of the Council which shall have received the expressed or the implied sanction of the membership at the next subsequent meeting of the Society shall be deemed to be the act of the Society, and shall not afterward be impeached by any member.

C 25. The Council may, by a two-thirds vote of the members present, declare any elective office vacant, on the failure of its incumbent for one year, from inability or otherwise, to attend the Council meetings, or to perform the duties of his office, and shall thereupon appoint a Member or Associate to fill the vacancy until the next Annual Meeting. The said appointment shall not render the appointee ineligible to election to any office.

OFFICERS.

C 26. At each Annual Meeting there shall be elected from among the Members and Associates:

A President to hold office for one year.

Two Vice-Presidents, one to hold office for one year and one to hold office for two years. After the first year one Vice-President to be elected annually for a term of two years.

A Treasurer to hold office for one year.

Nine Members or Associates shall be elected to the Council at the first Annual Meeting, three to hold office for one year, three to hold office for two years, and three to hold office for three years, and at each subsequent Annual Meeting three Members or Associates shall be elected, each to serve three years.

C 27. The election of officers shall be by ballot, as the By-Laws shall provide.

C 28. The term of all elective officers shall begin on the adjournment of the Annual Meeting of the Society. Officers shall

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continue in their respective offices until their successors have been installed.

C 29. A President or Vice-President shall not be eligible for immediate re-election to the same office at the expiration of the term for which he was elected.

C 30. The Council, at its first meeting after the Annual Meeting of the Society, shall appoint a Member or Associate to serve as Secretary of the Society subject to the pleasure of the Council. The Secretary shall receive a salary which shall be fixed by the Council at the time of his appointment.

C 31. The President, Secretary and Treasurer shall perform the duties legally or customarily attaching to their respective offices under the laws of the State of New York, and such other duties as may be required of them by the Council.

C 32. A vacancy in the office of President shall be filled by the Vice-President who is senior by age.

MEETINGS.

C 33. The Society shall hold its Annual Meeting in New York City on the Monday preceding the first Tuesday in December, and such other meetings shall be held at such times and places as the Council may appoint. Twenty-five Members and Associates shall constitute a quorum for the transaction of business.

C 34. Special meetings of the Society may be called at any time at the discretion of the Council, or shall be called by the President upon the written request of twenty-five members entitled to vote.

C 35. Any appropriation recommended by the Society at a meeting shall not take effect until it has been approved by the Council.

C 36. Every question which shall come before a meeting of the Society or of the Council or a Committee shall be decided by a majority of the votes cast, unless otherwise provided in this Constitution or the By-Laws, or the laws of the State of New York. The Council may order the submission of any question to the membership for discussion by letter ballot. Any meeting of the Society at which a quorum is present may order the submission of any question to the membership for discussion by letter ballot.

STANDING COMMITTEES.

C 37. The standing committees of the Society shall be:

Finance Committee. Publication Committee.

Membership Committee.

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The members of these Committees shall be appointed by the President from members of the Council who are not officers of the Society.

TRANSACTIONS.

C 38. The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings. Matters relating to politics, religion or purely to trade shall not be discussed at a meeting of the Society nor be included in the Transactions.

C 39. The Society shall not approve any engineering or commercial enterprise, nor allow its imprint or name to be used in any commercial work or business. No member shall describe himself in connection with the Society in any advertisement other than as a Member, Associate Member or Junior Member.

AMENDMENTS.

C 40. At Annual Meetings of the Society any Member or Associate may propose in writing for discussion an amendment to this Constitution. Such proposed amendment shall not be voted on at that meeting, but shall be open for discussion and such modification as may be accepted by the proposer. The proposed amendment shall be mailed by the Secretary to each Member and Associate at the time the notice of the next Annual Meeting issues, and shall be voted upon at said meeting.

C 41. Such By-Laws shall be enacted as will conform with this Constitution and the laws of the State of New York and as are required to conduct the business of the Society.

BY-LAWS.

CANDIDATES FOR MEMBERSHIP.

B 1. A candidate for admission to the Society as a Member or as an Associate must make application on a form approved by the Council, upon which he shall write a statement giving a complete account of his qualifications and engineering experience, and an agreement that he will, if elected, conform to the Constitution, By-Laws and Rules of the Society. He must refer to at least four Members or Associates to whom he is personally known.

B 2. Applications for membership from Refrigerating En-

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gineers who are not residents in the United States or Canada and who may be so situated as not to be personally known to four Members or Associates of the Society, as required in the foregoing paragraph, may be recommended for ballot by four members of the Council, after sufficient evidence has been secured to show that in their opinion the applicant is worthy of admission to the grade which he seeks.

B 3. A candidate for admission to the Society as a Junior must make application in the same manner as provided for Members or Associates, except that he must refer to not less than three Members or Associates to whom he is personally known.

B 4. The references for each candidate for admission to the Society shall be requested to make a confidential communication to the Membership Committee, setting forth in detail such information, personally known to the referee, as shall enable the Council to arrive at a proper estimate of the eligibility of the candidate for admission to the Society.

ELECTION OF MEMBERS.

B 5. The Secretary shall mail to each member entitled to vote, at least thirty days in advance of any meeting, a ballot stating the names and the respective grades of the candidates for membership in the Society which have been approved by the Council, and the time of the closure of voting. The voter shall prepare his ballot by crossing out the names of candidates rejected by him, and shall enclose said ballot in a sealed blank ballot envelope, which he shall then enclose in a second sealed outer envelope, on which he shall, for identification, write his name in ink. The ballot thus prepared and enclosed shall be mailed or delivered unopened to the Tellers of Election. The Secretary shall certify to the competency and the signature of all voters. On the closure of voting, the Tellers of Election shall first open and destroy the outer envelopes, and shall then canvass the ballots, and certify the result to the meeting of the Society.

B 6. The Tellers of Election shall not receive any ballot after the stated time of the closure of voting. A ballot without the endorsement of the voter written in ink on the outer envelope is defective, and shall be rejected by the Tellers of Election.

B 7. The names of those persons elected to membership, with their respective grades, shall be embodied in a written report, signed by the Tellers, and presented to the next meeting of the Society. The President shall then declare them duly elected to membership

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in the Society. The Tellers may, through the Secretary, in advance of any meeting, advise each candidate of the result of the canvass of the votes in his case. The names of applicants who are not elected shall neither be announced nor recorded in the Transactions.

B 8. The endorsers of an applicant who has not been elected may, with his consent, present to the Council a written request for a re-submission of his name to ballot. The Council may, in its discretion, by a three-fourths vote of the members present, order the name of the applicant placed on the next ballot for members.

B 9. Each person elected to membership must subscribe to the Constitution, By-Laws and Rules of the Society, and pay the initiation fee before he can receive a certificate of membership in the Society.

ELECTION OF OFFICERS.

B 10. The Secretary shall mail to each member entitled to vote, at least thirty days before the Annual Meeting, the names of the candidates for office proposed for election by the Nominating Committees.

B 11. The names of the candidates proposed by the Nominating Committee or Committees, and the respective offices for which they are candidates, shall be printed in separate lists on the same ballot sheet, each list of candidates to be printed under the names of the members of the particular committee which proposed it.

B 12. The name of any candidate on the ballot may be erased, and the name of any person qualified to hold the office written in its stead. The ballot must be voted and canvassed in the same manner as for the election of members.

B 13. In case of a tie in the vote for any officer, the President, or, in his absence, the Presiding Officer, shall cast the deciding vote.

B 14. A ballot which contains more names on it than there are officers to be elected is thereby defective, and shall be rejected by the Tellers.

FEES AND DUES.

B 15. The initiation fee and annual dues of the first year shall be due and payable on notice of election to membership. Thereafter the annual dues shall be due and payable on the first day of December in each year.

B 16. A member in arrears for one year shall not be entitled to vote until such arrears have been paid. Should the right to vote be questioned, the books of the Society shall be conclusive evidence.

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B 17. The Secretary shall present to the Council the name of any Member, Associate or Junior in arrears for more than one year. A person dropped from the rolls for non-payment of dues may, at the discretion of the Council, be restored to the privileges of membership, upon payment of all arrears.

FINANCIAL ADMINISTRATION.

B 18. The Council at its first meeting in each fiscal year shall consider the recommendations of the Finance Committee concerning the expenditures necessary for the work of the Society during that year. The apportioning of the work of the Society among the various standing and other Committees shall be on a basis approved by the Council and in harmony with the Constitution and By-Laws. The appropriations approved by the Council, or so much thereof as may be required for the work of the Society, shall be expended by the various Committees of the Society, and all bills against the Society for such expenditure shall be certified by the Committee making the expenditure and shall then be sent to the Finance Committee for audit. Money shall not be paid out by any officer or employee of the Society except upon bills duly audited by the Committee, or by resolution of the Council.

FINANCE COMMITTEE.

B 19. The Finance Committee shall consist of three members of the Council appointed for a term of one year. The Committee shall, under the direction of the Council, have supervision of the financial affairs of the Society, including the books of account.

PROGRAMME COMMITTEE.

B 20. The President shall appoint a Committee from the members of the Council who shall procure professional papers, to pass upon their suitability for presentation, and to suggest topical subjects for discussion at the meetings. The Committee may refer any paper presented to the Society to a person or persons, especially qualified by theoretical knowledge or practical experience, for their suggestions or opinions as to the suitability of the paper for presentation. Papers from non-members shall not be accepted except by unanimous vote of the Committee. The Committee shall arrange the programme of each meeting of the Society, and shall have general charge of the entertainments to be provided for the members and

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guests at each meeting. It shall prohibit the distribution or exhibition at the headquarters or at the meeting places of the Society of all advertising circulars, pamphlets or samples of commercial apparatus or machinery. At the end of each fiscal year the Committee shall deliver to the Secretary for presentation to the Council a detailed report of its work.

PUBLICATION COMMITTEE.

B 21. The Publication Committee shall consist of three members of the Council appointed for a term of one year. The Committee shall review all papers and discussions which have been presented at the meetings, and shall decide what papers or discussions, or parts of the same, shall be printed. At the end of each fiscal year the Committee shall deliver to the Secretary for presentation to the Council a detailed report of its work.

MEMBERSHIP COMMITTEE.

B 22. The Membership Committee shall consist of three members of the Council appointed for a term of one year. It shall be the duty of this Committee:

To receive and scrutinize all applications for membership to the Society.

To seek further information as to the qualifications of any applicant whose evidence of eligibility is not clear to the Committee.

To report to each session of the Council the names of all applicants under consideration, together with the action of the Committee on each.

The Committee shall at once destroy all correspondence in relation to each applicant when his name has been placed on the ballot by order of the Council, or upon the withdrawal of the application.

NOMINATING COMMITTEE.

B 23. A Nominating Committee of five Members or Associates shall be appointed by the President within three months after he assumes office. It shall be the duty of this Committee to send to the Secretary on or before October first the names of consenting nominees for the elective offices next falling vacant under the Constitution. Upon the request of any Member or Associate, the Secretary shall furnish to the applicant the names of such nominees.

B 24. A special Nominating Committee, if organized, shall,

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on or before October twentieth, present to the Secretary the names of the candidates nominated by it for the elective offices next falling vacant under the Constitution, together with the written consent of each.

TELLERS.

B 25. The Presiding Officer shall, at the first session of the Annual Meeting, appoint three Tellers of Election of Officers, whose duties shall be to canvass the votes cast, and report the result to the meeting. Their term of office shall terminate when their report of the canvass is presented to the meeting.

B 26. The President within one month after assuming office shall appoint three Tellers of Election of Members to serve for one year, whose duties shall be to canvass the votes cast for members during the year, and to certify the same to the President. They shall notify candidates through the Secretary of the result of such election.

B 27. The President shall appoint three Tellers to canvass any letter ballots which shall be ordered by the Council or by the Society.

SECRETARY.

B 28. The Secretary of the Society shall be the Secretary to the Council.

The Secretary shall, under the supervision of the Finance Committee, have charge of the Books of Account of the Society.

He shall make and collect all bills against members or others.

All bills against the Society shall be delivered to the Secretary. He shall immediately enter them in the books of account, and shall immediately deposit such funds as he receives to the credit of the Society in a bank to be designated by the Council.

TREASURER.

B 29. The Treasurer shall make payments only on the audit of the Finance Committee, or upon the direction of the Council, by resolution of that body. He shall furnish a bond for the faithful performance of his duties to such amount as the Council may require, such bond to be procured from an incorporated Guarantee Company, at the expense of the Society.

TITLES, EMBLEMS, CERTIFICATES.

B 30. Each Member, Associate and Junior shall, subject to such rules as the Council may establish, be entitled on request to

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a certificate of membership, signed by the President and Secretary of the Society. Every such certificate shall remain the property of the Society, and shall be returned to it on demand of the Council.

B 31. Each proxy authorizing a person to vote for an absent member shall be signed by such absent member, with an attesting witness, and be submitted to the Secretary for verification of the member's right to vote at the meeting at which the right is to be exercised.

B 32. The emblem of each grade of membership approved by the Council shall be worn by those only who belong to that grade. The official stationery shall be used only by Officers and Committees of the Society for official business.

B 33. The abbreviations of the titles of the various grades of membership approved by the Society are as follows:

For Members—Mem. Am. Soc. R. E.
For Associates—Assoc. Am. Soc. R. E.
For Juniors—Jun. Am. Soc. R. E.

ORDER OF BUSINESS.

B 34. Roll Call.
Reading of minutes of previous meeting.
Report of Tellers of Election of Membership.
Report of the Council.
Unfinished business.
New business.
Report of Tellers of Election of Officers.
Reading of papers and discussions.

PARLIAMENTARY RULES.

B 35. In all questions arising at any meeting, involving parliamentary rules not provided for in these By-Laws, "Cushing's Manual" shall be the governing authority.

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PROCEEDINGS

OF THE

SECOND ANNUAL MEETING

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

New York, N. Y., December 3 and 4, 1906.

The Society held its second annual meeting in New York, N. Y., on Monday and Tuesday, December 3 and 4, 1906, in the society house of the American Society of Mechanical Engineers, No. 12 West Thirty-first street. Four sessions were held, Monday morning, afternoon and evening, and Tuesday morning, all being called to order by President W. Everett Parsons.

First Session, Monday Morning, December 3.

The first session of the meeting was called to order at about 10 A. M., and the following members responded to the roll call:

Borgstedt, Henning,
New Rochelle, N. Y.
Botchford, Henry J....Boston, Mass.
Brownell, C. H.,
Washington Court House, Ohio
Burhorn, Edwin....New York, N. Y.
Cary, Albert A.....New York, N. Y.
Cole, Harold W.,
Upper Montclair, N. J.
Collins, John Glenn.....Chicago, Ill.
De Kinder, J. J.....Philadelphia, Pa.
Dickerman, Charles.Philadelphia, Pa.
Ely, James.....New York, N. Y.
Friedmann, Edward N.,
New York, N. Y.
Greene, Van Rensselaer H.,
New York, N. Y.
Gueth, Oswald.....Brooklyn, N. Y.
Haire, David E.....Philadelphia, Pa.
Hart, B. Franklin, Jr.,
New York, N. Y.
Haven, Harry M...Somerville, Mass.
Herst, Franklin H..Philadelphia, Pa.
Jacobus, D. S.....New York, N. Y.
Jenks, L. Howard..New York, N. Y.
Louis, J. S.....Cincinnati, Ohio
Matthews, F. E.....Hartford, Conn.
Morris, O. J.....Dallas, Texas
Parsons, W. Everett,
New York, N. Y.
Penney, Edgar.....Newburgh, N. Y.
Phillips, Ellis L....New York, N. Y.
Pilsbry, F. W.....Chicago, Ill.
Roelker, H. B.....New York, N. Y.
Ross, William H...New York, N. Y.
Rowe, Samuel J....New York, N. Y.
Shipley, Samuel J...New York, N. Y.
Shipley, Thomas.....York, Pa.

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Shipman, R. L.....Ithaca, N. Y.
Starr, John E.....New York, N. Y.
Tinker, Henry W.....Boston, Mass.
Torrance, Henry, Jr., New York, N. Y.
Vesterdahl, Karl E., New York, N. Y.
Vollmann, Carl W..Montreal, Canada
Voorhees, Gardner T., New York, N. Y.
Wait, John C.....New York, N. Y.
Wegemann, Karl...New York, N. Y.
Werliin, Louis.....Philadelphia, Pa.
White, Frank H....Montreal, Canada
Williams, Llewellyn...Boston, Mass.
Wills, James.....New York, N. Y.

The minutes of the first annual meeting were then read and approved. They were as follows:

MINUTES OF THE FIRST ANNUAL MEETING OF THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

The First Annual Meeting of The American Society of Refrigerating Engineers was held in New York, N. Y., pursuant to the provisions of its Constitution and Charter, issued under the laws of the State of New York, on Monday and Tuesday, December 4 and 5, 1905. Four sessions were held, Monday morning, afternoon and evening and Tuesday morning, all being called to order by Mr. John E. Starr, the first president of the Society, in the chambers of the American Society of Mechanical Engineers, No. 12 West Thirty-first street.

The opening session was called to order on Monday, December 4, shortly after 9:30 A.M., and after calling the roll of Charter Members, and a quorum being announced, the minutes of the organization meeting were read and approved.

The report of the Tellers of Election of Membership was then received. They reported that fifteen applicants for membership in the grade of Member, thirty-one in the grade of Associate and three in the grade of Junior had been elected to membership. The President then announced that the successful applicants were duly elected to their respective grades and entitled to the rights and privileges of membership, if they had complied with the Constitution and By-Laws covering new members.

The report of the Council was next received and approved.

The Council reported the death of Mr. Rockwell King, and the President appointed a committee of two to draft suitable resolutions and report at the last session of the meeting.

On being questioned, the President stated, under the advice of the Council, and without disregarding the order of the Society, that he had not appointed the committee to investigate and report on the establishing of a standard unit ton for refrigerating machines, which he had been requested to do at the organization meeting, for the reason that he thought it well to defer the appointment of the committee until what seemed to the Council to be a somewhat more favorable opportunity, especially as a committee of the American Society of Mechanical Engineers had taken up the subject and had not completed its labors.

J. Shipman Louis then presented an amendment to paragraph C 33, under the division of "Meetings," of the Constitution, in accordance with paragraph C 40, under the division of "Amendments," of the Constitution, for discussion.

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Final action to be taken at the next annual meeting. The proposed amendment is as follows:

"Where paragraph C 33 of the Constitution reads 'The Society shall hold its Annual Meeting in New York City in the month of December,' I would have it read 'The Society shall hold its Annual Meeting in New York City on the Monday preceding the first Tuesday in December,' in order that it may be in accord with our charter, as the laws of the State of New York require that the date of the Annual Meeting of a corporation be specifically given in its articles of association."

He further proposed an amendment to paragraph B 34, under the division "Order of Business" of the By-Laws. This paragraph now reads:

B 34. *a.* Roll Call.
b. Reading of minutes of previous meeting.
c. Report of Officers—President, Secretary, Treasurer.
d. Reports of standing and special committees.
e. Unfinished business.
f. Report of tellers of election.
g. New business.
h. Reading of papers and discussions.

Mr. Louis would have this paragraph read:

B 34. Roll Call.
Reading of minutes of previous meeting.
Report of the Tellers of Election of Membership.
Report of the Council.
Unfinished business.
New business.
Report of the Tellers of Election of Officers.
Reading of papers and discussions.

It was claimed that under the latter proposed amendment the annual meetings would be conducted in greater harmony with the provisions of the Constitution and By-Laws covering these points.

The matter of amending the By-Laws was brought up, as the By-Laws contain no provision for making amendments, and the President ruled that the By-Laws could be amended in the same manner as the Constitution.

The next order of business was the report of the Tellers of Election of Officers. They reported that W. Everett Parsons had been elected President; John E. Starr, Vice-President; Walter C. Reid, Treasurer, and Louis Block, Edgar Penney and H. B. Roelker, Directors. The President announced that they had been duly elected to their respective offices and invited President-elect Parsons to sit with him during the balance of the meeting.

President-elect Parsons, after being escorted to a seat beside the President, stated that he appreciated the honor very much and would do his best to serve the Society.

The address of the President was now had.

Following the address of the President, he read a paper on "Pipe Line Refrigeration."

The session adjourned at this point and all retired to the supper room in the basement, where the Programme Committee had lunch served.

SECOND SESSION, MONDAY AFTERNOON, DECEMBER 4.

The meeting was called to order shortly after 1 P. M. The following four papers were presented at this session:

"Elements Governing the Selection of the 'Plate' System and the 'Can' System," by Edgar Penney; "Cold Storage Requirements for the Refrigeration

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of Perishable Food Products," by W. T. Robinson; "The Transportation of Fruit in Refrigeration," by G. Harold Powell; "Furs and Fabrics in Cold Storage," by Walter C. Reid.

After Mr. Robinson had finished reading his paper he stated that he desired to move the following resolution, but before doing so he would like to hear from G. Harold Powell, of the United States Department of Agriculture, who was present, if he thought it covered the ground:

WHEREAS, The work of the Agricultural Department in its investigations and reports on the preservation of fruits and food products is giving the producers and consumers thereof valuable information; therefore be it

Resolved, That The American Society of Refrigerating Engineers, in convention assembled, recommends that Congress appropriate a sufficient amount to enable the Agricultural Department to equip and maintain a cold storage plant for making such investigations as may be recommended by the Secretary of the United States Department of Agriculture.

Mr. Powell approved of the resolution.

Mr. Robinson then offered his resolution and it was unanimously accepted, and a copy was ordered sent to the Secretary of the Agricultural Department.

On motion, duly made and seconded, the unanimous thanks of the Society were extended to Mr. Powell for his very interesting paper.

THIRD SESSION, MONDAY EVENING, DECEMBER 4.

The session was called to order at 8 P. M. The papers read at this session were as follows:

"The Evaporator and Its Use in the Manufacture of Can Ice," by Louis Block; "Does a 100-Ton Ammonia Compression Plate Ice-Making Plant or a 100-Ton Absorption Plate Ice-Making Plant Equal in Economy a 50-Ton Compression Machine in Combination with a 50-Ton Absorption Machine, Using the Exhaust of the Compression Machine for Operating the Absorption Machine?", by Henry Torrance, Jr.; "The Carbonic Acid Refrigerating Machine," by J. C. Goosmann.

No discussion was had on Mr. Goosmann's paper, as he was unable to be present to read it and participate in the debate. The paper was read by Oswald Gueth.

FOURTH SESSION, TUESDAY MORNING, DECEMBER 5.

The final session of the meeting was called to order shortly after 9 A. M. The following papers were presented:

"The Practical Value of Indicating the Ammonia Compressor," by W. Everett Parsons; "Requirements of Small Refrigerating Plants of Less Than One Ton Capacity," by Martin R. Carpenter.

The following topical discussions also received the attention of this session:

"Brine versus Direct Expansion in Plate Ice-Making Plants," "Is Top Expansion or Bottom Expansion Best in Can Freezing Systems?", "Principal Cause of Non-Condensable Gases in Ammonia Machines," "Best Method of Removing Oil from Hot Ammonia Gas," "Under What Conditions Does It Pay to Use a Cooling Tower?", "Is NH_3 Inflammable?" and "Experience in the Use of Boiler Compounds in Can Ice Plants."

In the course of the discussion on Mr. Parsons' paper Thomas Shipley, on behalf of the York Manufacturing Company, of York, Pa., extended an invitation to the Society to send a committee to visit its test plant at York,

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Pa., to establish data on mechanical refrigeration. Mr. Shipley also kindly offered to furnish the necessary men to operate the test plant while any tests the committee might care to make were in progress.

A motion prevailed tendering the thanks of the Society to the York Manufacturing Company and its general manager, Thomas Shipley, for the kind invitation to use the experimental plant.

The President announced that owing to a death in the family of John C. Wait he was prevented from attending and reading his paper on "Engineer's Specifications versus Contractor's Warranty," and further stated that he felt it was a disappointment to all and that the sympathy of each member went out to Mr. Wait in his bereavement.

Announcement was made that the papers read at the meeting, as well as the discussions had thereon, would be printed in the two trade journals devoted to mechanical refrigeration—*Ice and Refrigeration* and *Cold Storage and Ice Trade Journal.*

The report of the committee appointed at the first session of the meeting to draft resolutions on the death of Rockwell King reported as follows, which was unanimously approved:

WHEREAS, In the death of Mr. Rockwell King, The American Society of Refrigerating Engineers has lost a Charter Member who, had he lived, would have been of much service to the Society in the work it is doing; therefore be it

Resolved, That this Society, at its First Annual Meeting, held in New York, N. Y., December 4 and 5, 1905, wishes to express its sincere sympathy with the family of Mr. King, and feels that it has met with an irreparable loss in not having his wise counsel and mature judgment to assist the Society at this time.

Resolved, That this resolution be spread upon the minutes and that a copy be sent to the family of Mr. King.

(Signed) W. T. ROBINSON,
C. H. BROWNELL.

A vote of thanks was extended to the American Society of Mechanical Engineers for the use of its premises and the many other courtesies shown.

A unanimous vote of thanks was extended to the President for the uniform courtesy and great capacity with which he discharged the duties of his office.

The meeting then adjourned.

W. H. Ross, Secretary.

The report of the Tellers of Election of Membership was now received. It was as follows:

REPORT OF TELLERS OF ELECTION OF MEMBERSHIP.

NEW YORK CITY, November 19, 1906.

MR. W. EVERETT PARSONS, PRESIDENT,
The American Society of Refrigerating Engineers,
No. 258 Broadway, New York City.

Dear Sir:

Your Tellers of Election of Membership met on this date and canvassed the ballots for new members, as prescribed in the Constitution and By-Laws,

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and beg to report that the following new members have been duly elected to membership in this Society in their respective grades as indicated:

MEMBERS.

Julius W. Birkholz...Newark, N. J.
Edward John Gardiner, Sydney, Australia
Otto Luhr.....Chicago, Ill.
Charles E. B. McReddie, Buenos Aires, Argentine Republic
Rey y Basadre, José Santiago, Buenos Aires, Argentine Republic
Ambrose B. Strickler.....York, Pa.
Abel Winborg.....York, Pa.
Conrad H. Young.....Chicago, Ill.
Carlos Maschwitz, Buenos Aires, Argentine Republic

ASSOCIATE MEMBERS.

W. D. Ashton Bost, Paisley, Scotland
Charles Louis Criss....Pittsburg, Pa.
O. M. Gould.....Montreal, Canada
Albert Johnson.....St. Louis, Mo.
Charles A. L. Loney, Sydney, Australia
John A. Ruddick.....Ottawa, Canada
Allston Sargent....New York, N. Y.
John C. Sparks....New York, N. Y.
Junius H. Stone....New York, N. Y.
Frederick Widmann...St. Louis, Mo.

JUNIOR MEMBERS.

William B. Affleck..Philadelphia, Pa.
David L. Fagnan....Cleveland, Ohio
George V. K. Greene, New York, N. Y.
Charles H. Guckel..New York, N. Y.
Alexander S. Mitchell, Wellington, New Zealand
Frank J. Roos.....Chicago, Ill.
William S. Shipley..New York, N. Y.
Irving Warner.....Wilmington, Del.
Carl Bloom Wolf, Philadelphia, Pa.

We have also to further report that Robert A. Whelan, of Chicago, Ill., now an Associate Member, has been elected a Member.

Respectfully submitted,
H. F. Salkeld,
W. Fellows Morgan,
Benjamin F. Daly,
Tellers of Election of Membership.

The President declared the successful applicants for membership duly elected to their respective grades, and requested the Secretary to call the roll of new members. The following responded:

Affleck, William B..Philadelphia, Pa.
Birkholz, Julius W....Newark, N. J.
Sargent, Allston....New York, N. Y.
Shipley, William S., New York, N. Y.
Sparks, John C.....New York, N. Y.
Stone, Junius H....New York, N. Y.
Strickler, Ambrose B.....York, Pa.
Warner, Irving....Wilmington, Del.

The report of the Council was now heard and accepted. It was as follows:

REPORT OF THE COUNCIL OF THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS FOR THE FISCAL YEAR ENDING DECEMBER 1, 1906.

Three executive sessions of the Council have been held during the past year, and it respectfully presents herewith a report of the business transacted, pursuant to the provisions of the Constitution and By-Laws.

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The amount of real and personal property owned by the Society, the property acquired during the year, the amount applied, appropriated or expended, and the purposes and objects for which such expenditures have been made, are contained in the report of the Finance Committee, which follows:

NEW YORK, December 1, 1906.

REPORT OF THE FINANCE COMMITTEE FOR THE FISCAL YEAR ENDING DECEMBER 1, 1906.

RECEIPTS.

Initiation fees	$170.00	
Dues	945.00	
Emblems	84.75	
Banquet	165.00	
Stenographer	101.94	
Total receipts		$1,466.69
Balance on hand December 1, 1905		602.17
Grand total		$2,068.86

DISBURSEMENTS.

Caterers	$228.70	
Emblems	112.50	
Stenographer	150.00	
Office furniture	29.85	
Membership certificates	14.75	
Premium on Treasurer's bond	5.00	
Printing	625.73	
Rent of A. S. M. E. rooms	65.00	
Salaries	416.67	
Petty cash	148.91	
		$1,797.11
Balance on hand		$271.75

Respectfully submitted,

(Signed) EDGAR PENNEY, Chairman.
H. B. ROELKER.
THOMAS SHIPLEY.

William H. Ross was reappointed Secretary of the Society, subject to the pleasure of the Council, at its first meeting at a salary of $400 a year.

The Council had 1,000 copies of the Year Book printed, also 500 copies of the Transactions. Only 250 copies of the Transactions were bound. About 300 copies of the Year Book are on hand.

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The following have been elected to membership in the Society in the three grades during the year:

MEMBERS.

Julius W. Birkholz, Newark, N. J.
Edward John Gardiner, Sydney, Australia.
Otto Luhr, Chicago, Ill.
Carlos Maschwitz, Buenos Aires, Argentine Republic.
Charles E. B. McReddie, Buenos Aires, Argentine Republic.
José Santiago Rey y Basadre, Buenos Aires, Argentine Republic.
Ambrose B. Strickler, York, Pa.
Abel Winborg, York, Pa.
Conrad H. Young, Chicago, Ill.

ASSOCIATES.

W. D. Ashton Bost, Paisley, Scotland.
Charles Louis Criss, Pittsburgh, Pa.
O. M. Gould, Montreal, Canada.
Albert Johnson, St. Louis, Mo.
Charles A. L. Loney, Sydney, Australia.
John A. Ruddick, Ottawa, Canada.
Allston Sargent, New York, N. Y.
John C. Sparks, New York, N. Y.
Junius H. Stone, New York, N. Y.
Frederick Widmann, St. Louis, Mo.

JUNIORS.

William B. Affleck, Philadelphia, Pa.
David L. Fagnan, Cleveland, Ohio.
George V. K. Greene, New York, N. Y.
Charles H. Guckel, New York, N. Y.
Alexander S. Mitchell, Wellington, New Zealand.
Frank J. Roos, Chicago, Ill.
William S. Shipley, New York, N. Y.
Irving Warner, Wilmington, Del.
Carl Bloom Wolf, Philadelphia, Pa.

Thirteen additional applications for membership, including one for change of grade of membership, are now before the Membership Committee for investigation, the majority of which have been received since the ballot for new members issued.

The Membership Committee held two sessions during the year and carefully investigated the experiences and qualifications of all applicants.

Your President made the following committee appointments on February 2:

MEMBERSHIP.

L. Howard Jenks, chairman.

W. T. Robinson. Louis Block.

FINANCE.

Edgar Penney, chairman.

Thomas Shipley. H. B. Roelker.

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PUBLICATION.

D. S. Jacobus, chairman.

Henry Torrance, Jr. Ellis L. Phillips.

PROGRAMME.

John E. Starr, chairman.

D. S. Jacobus. Thomas Shipley. Henry Torrance, Jr.

H. F. Salkeld, W. Fellows Morgan and Benjamin F. Daly were appointed Tellers of Election of Membership on January 3. These tellers met on November 19 and canvassed the ballots.

The Nominating Committee, consisting of Karl E. Vesterdahl, Carl W. Vollmann, Harold W. Cole, Henry Vogt and Bernard Voss, appointed by your President on May 11, met on August 8, and selected members to fill the offices next falling vacant under the Constitution, and made its report on September 28. In its report the Nominating Committee recommends that three new directors be selected each year, the new vice-president being selected from the retiring directors and the retiring vice-president be made the nominee for president.

The Programme Committee has met several times to prepare an interesting programme for this meeting and arrange for your comfort.

The Finance Committee reports progress in securing quarters for the Society in the new Engineering Societies Building. This building is not yet ready for occupancy.

The Council at its first meeting decided that the membership of the Society was not yet large enough, particularly in the West, to hold a spring meeting, especially as it thought that if a spring meeting was held it should be in the West.

The Council reported at the last annual meeting that it hoped the finances of the Society would permit the issuing of printed copies of the papers to be read at this meeting in advance of the meeting. The heavy draft made on the Treasurer for the printing of the Transactions made this unwise at this time. The increase in membership this year will probably admit of doing so, however, in advance of the next annual meeting.

Again the Council has to report the death of one of our members, Mr. Edmund J. Smith, president of the Memphis Machine Works, Memphis, Tenn. Mr. Smith died in Memphis on September 17, of this year, from injuries received by being thrown from a horse on the day of his death.

The Publication Committee reports that the Transactions for 1905 are now being delivered. They have been gotten up in a very substantial form and are not lacking in artistic value. This committee has spent a great amount of time and labor on this volume, and while a little late in delivery, owing to the many details that must be worked out in the first edition of any work, it is to be hoped that they will be valued highly by the membership.

The Council has established that all members of the Society at the time of a regular annual meeting shall receive a copy of the Transactions for that year, provided they have paid their dues. The Council has further established that members can secure additional copies of the Transactions at $5 per copy, and that non-members can purchase copies of the Transactions at $10 per volume.

The Council at its first meeting voted to accept the kind invitation of the York Manufacturing Company, made through its general manager, Mr.

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Thomas Shipley, at our last annual meeting, to use its test plant for establishing data on mechanical refrigeration. Your President appointed Vice-President John E. Starr, Carl W. Vollmann, Llewellyn Williams, Director Thomas Shipley and John S. De Hart, Jr., as a committee to visit this test plant and conduct tests along lines that it felt were most important, but suggested, on the advice of the Council, that tests on "Dry versus Wet Compression" and "Flooded Coils Systems" receive attention. Your President hopes they will find it convenient to report some time during this meeting.

Your President has appointed the following as Tellers of Election of Officers: Prof. R. L. Shipman, John Glenn Collins and Charles Dickerman.

The Council has established that no member shall use a fac-simile of the seal or emblem of the Society on his stationery, personal or business cards, or in any advertisement.

In the report of the Membership Committee to the Council on July 11 it had the following to say:

"At a meeting of the Membership Committee held on May 15, 1906, the applications for membership before it for action were considered under the following interpretations of the provisions of the Constitution relative to the matter:

"That the Constitution does not in effect create a grade between Associate and Member, but classifies the available membership according to their respective lines of work; that is to say, a Member should have sufficient technical education, knowledge of the theory of thermodynamics and experience to enable him to be a designer or constructor of refrigerating machinery.

"An Associate should have such training, knowledge and experience as to enable him to co-operate with refrigerating engineers or have expert knowledge in correlative branches of refrigerating engineering.

"A Junior should have some technical training and knowledge of refrigeration, but not having acquired sufficient experience in this line to qualify as a Member.

"Under these interpretations of the Constitution it is evident that an applicant of technical training or practical experience not fully qualified to admission as a Member should not apply as an Associate, but as a Junior. The fact that an applicant is a chief engineer of a plant, or in fact that he may hold any particular position in the refrigerating line, is not the determining factor in passing on his application, but should be considered solely on the fitness of the individual to come under the classification for which he applies."

The Council has accepted these interpretations of the Membership Committee.

The Council has also established that the prices of its emblem in the form of a button, pin, stickpin or charm shall be $2.75 each.

On the invitation of the Provost and Trustees of the University of Pennsylvania to have a representative of this Society present at the dedication of its new engineering building on October 19, your President appointed Director W. T. Robinson to represent the Society on this occasion.

Respectfully submitted,

W. Everett Parsons, *President.*

The amendment to the Constitution and the amendment to the By-Laws, introduced at the first annual meeting by J. Shipman

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Louis, were now taken up for final discussion and action. After some discussion they were unanimously approved. They are as follows:

NEW YORK CITY, December 4, 1905.

AMENDMENTS PROPOSED.

In accordance with paragraph C 40, under the division of "Amendments" of the Constitution, I beg to propose an amendment to paragraph C 33, under the division of "Meetings" of the Constitution, for discussion at this meeting and for final action at the next Annual Meeting, as the Constitution provides.

Where paragraph C 33 of the Constitution reads "The Society shall hold its Annual Meeting in New York City in the month of December," I would have it read "The Society shall hold its Annual Meeting in New York City on the Monday preceding the first Tuesday in December," in order that it may be in accord with our charter, as the laws of the State of New York require that the date of the Annual Meeting of a corporation be specifically given in its articles of association.

I also propose an amendment to paragraph B 34, under the division, "Order of Business," of the By-Laws. This paragraph now reads as follows:

B 34. *a.* Roll Call.
b. Reading of minutes of previous meeting.
c. Report of Officers—President, Secretary, Treasurer.
d. Reports of standing and special committees.
e. Unfinished business.
f. Report of tellers of election.
g. New business.
h. Reading of papers and discussions.

I propose that it read:

B 34. Roll Call.
Reading of minutes of previous meeting.
Report of Tellers of Election of Membership.
Report of the Council.
Unfinished business.
New business.
Report of the Tellers of Election of Officers.
Reading of papers and discussions.

Under the latter proposed amendment the Annual Meetings will be conducted in greater harmony with the provisions of the Constitution and By-Laws covering these points.

(Signed) J. SHIPMAN LOUIS (Proposer).

President Parsons next called for the report of the committee that was appointed at the first annual meeting to visit the test plant of the York Manufacturing Company, at York, Pa., to conduct tests on problems connected with mechanical refrigeration. Vice-President John E. Starr, chairman of the committee, made an informal report as follows:

"Mr. President, I am sorry to say that this committee will be unable to make a report at this meeting. The causes are twofold. All of the members

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of the committee were pretty busily engaged this year, but that would not have prevented the investigations at York. It just so happened that it was inconvenient for the York Manufacturing Company to have the experiments conducted early in the year, and later, in October, there were only two of the committee available. The committee also felt that while Mr. Shipley stood by his invitation, their shop was so crowded with work that it would be a matter of great inconvenience to them to take up the subject. The matter was therefore left over."

The committee was continued.

The report of the Tellers of Election of Officers was now received. It was as follows:

REPORT OF THE TELLERS OF ELECTION OF OFFICERS.

NEW YORK, N. Y., December 3, 1906.

MR. W. EVERETT PARSONS, PRESIDENT,
The American Society of Refrigerating Engineers,
No. 258 Broadway, New York, N. Y.

Dear Sir:

Your Tellers of Election of Officers have canvassed the ballots and beg to report as follows:

President—Prof. D. S. Jacobus.
Vice-President—James Wills.
Treasurer—Walter C. Reid.

Directors { F. W. Pilsbry, J. J. de Kinder. L. Williams. }

Respectfully submitted,

R. L. SHIPMAN, JOHN GLENN COLLINS, CHARLES DICKERMAN, } *Tellers of Election of Officers.*

The President declared the new officers duly elected, and appointed Vice-President John E. Starr and Director Henry Torrance, Jr., to escort President-elect Jacobus to a chair beside him.

President-elect Jacobus thanked the members for the honor in the following words:

"Gentlemen—I wish to thank you very much for the extremely high honor which you have bestowed upon me. I will certainly do the very best I can to serve the Society in every way."

The address of President Parsons was now heard. It appears in these Transactions as one of the papers of the meeting.

Following his address, the President read a paper on "A Future for the Ice Manufacturing Industry."

The participants in the debate on President Parsons' paper were Henry Torrance, Jr., L. Howard Jenks, John E. Starr, Edgar Pen-

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ney, Gardner T. Voorhees, John N. Briggs, R. L. Shipman, H. B. Roelker, F. W. Pilsbry and the President.

H. B. Roelker then read a paper on "The Allen Dense Air Refrigerating Machine," and the following took part in the discussion: John E. Starr, Gardner T. Voorhees, O. J. Morris, J. S. Louis, L. Williams, H. B. Roelker and the President.

The session adjourned at this point for luncheon in the supper room, arranged for by the Programme Committee.

Second Session, Monday Afternoon, December 8.

The meeting was called to order about 1 P. M. The following four papers were presented at this session:

"Experiments on Binary Refrigeration," by Edgar Penney; "Description of a Cold Storage Plant Utilizing Exhaust Steam," by Henry Torrance, Jr.; "Refrigeration of Butter and Cheese," by C. E. Gray, and "Multiple Effect Compressors," by Gardner T. Voorhees.

A vote of thanks was extended Mr. Gray for his valuable paper.

The following took part in the discussion on the four papers:

On Mr. Penney's paper—John E. Starr.

On Mr. Torrance's paper—Gardner T. Voorhees, F. W. Pilsbry, Carl W. Vollmann and Mr. Torrance.

On Mr. Gray's paper—S. P. Stevenson, John E. Starr, Carl W. Vollmann and Mr. Gray.

On Mr. Voorhees' paper—Henry Torrance, Jr., D. S. Jacobus, L. Howard Jenks, John E. Starr, Irving Warner, Edgar Penney, Louis Sterne and Mr. Voorhees.

The topical discussion "How Can Leakage Be Prevented in Cellular Brine Plates?" was now taken up, and the participants in the discussion were Karl Wegemann, L. Howard Jenks, Gardner T. Voorhees, John E. Starr, Edgar Penney and Henry Torrance, Jr.

The session then adjourned.

Third Session, Monday Evening, December 8.

The meeting was called to order a few minutes after 8 P. M. The papers read at this session were: "Insulation," by Junius H. Stone; "The Water Jacketing of Ammonia Compressors," by R. L. Shipman, and "Engineer's Specifications versus Contractor's Warranty," by John C. Wait.

Following the reading of the papers, Harry Y. Norwood, Rochester, N. Y., gave an illustrated lecture on "Thermometry and

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Temperature Regulation." A vote of thanks was tendered Mr. Norwood for his interesting lecture.

Vice-President Starr acted as chairman during part of this session, taking the chair before Mr. Wait began to read his paper.

The following participated in the discussion on the three papers read at this session:

On Mr. Shipman's paper—L. Howard Jenks, John E. Starr, Gardner T. Voorhees, Henry Torrance, Jr., D. S. Jacobus, Edgar Penney and Mr. Shipman.

On Mr. Wait's paper—Edgar Penney, Oswald Gueth, L. Williams, Gardner T. Voorhees, L. Howard Jenks, the Chairman and Mr. Wait.

The session then adjourned.

Fourth Session, Tuesday Morning, December 4.

The last session of the meeting was called to order shortly after 9 A. M. The following papers were presented:

"Horse Power Per Ton of Refrigeration for Ammonia Compression Machines," by Thomas Shipley; "Data on Water Cooling Towers," by B. Franklin Hart, Jr., and "Oily Waters and Their Treatment," by Albert A. Cary.

Those that took part in the discussions were:

On Mr. Shipley's paper—Edgar Penney, R. L. Shipman, Gardner T. Voorhees, L. Williams, Carl W. Vollmann, Henry Torrance, Jr., and Mr. Shipley.

On Mr. Hart's paper—Edgar Penney, Albert A. Cary, John E. Starr, Henry W. Maurer, Edwin Burhorn, E. N. Friedmann and Mr. Hart.

On Mr. Cary's paper—John C. Sparks, E. N. Friedmann, L. Howard Jenks and Mr. Cary.

The additional topical discussions were now taken up. They were as follows:

"What Is the Best Method of Thawing Off Plate Ice?", "Is There Any Better Method of Making Can Ice Than the Usual Plan of Submerging Cans in Brine?", "What Precautions Are Necessary to Test Safely an Old Compression System with Air?", "Experience with Different Forms of Piston Rod Packing," and "Concrete Construction for Ice Tanks."

The participants in the debate on the topical discussions were: L. Howard Jenks, John E. Starr, Henry Torrance, Jr., Irving Warner, Thomas Shipley, D. S. Jacobus, E. N. Friedmann, R. L. Ship-

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man, O. J. Morris, Edgar Penney, L. Williams, J. S. Louis and the President.

J. J. de Kinder extended an invitation to those present to visit the new plant of the United Water Improvement Company, Philadelphia, Pa. H. N. Borgstedt extended an invitation on behalf of the De La Vergne Machine Company, New York, N. Y., to visit its plant, and all present were invited to witness an exhibition of "Thermit" welding by the Goldschmidt Thermit Company during the afternoon at its storeroom, No. 179 Christopher street.

A unanimous vote of thanks was extended to President Parsons for the able and pleasant way in which he carried out the arduous duties of his office.

The meeting then adjourned.

MEMBERS AND GUESTS ATTENDING MEETING.

Affleck, William B., Philadelphia, Pa.
Allison, C. E., New York, N. Y.
Andrews, J. G., New York, N. Y.
Batchelor, Charles, New York, N. Y.
Bates, A. B., Binghamton, N. Y.
Bates, Guy, Whippany, N. J.
Bellman, H. J., Philadelphia, Pa.
Bishop, A. C., Detroit, Mich.
Birkholz, Julius H., Newark, N. J.
Bonnell, C. E., Chicago, Ill.
Borgstedt, H. N., New York, N. Y.
Botchford, H. J., Boston, Mass.
Bower, William H., Philadelphia, Pa.
Bowers, James, Wilmington, Del.
Briggs, J. N., Coeymans, N. Y.
Brownell, C. H., Washington Court House, Ohio.
Bunnell, S. H., Watertown, N. Y.
Burhorn, Edwin, New York, N. Y.
Cary, Albert A., New York, N. Y.
Clemens, A. B., Scranton, Pa.
Cole, Harold W., New York, N. Y.
Collins, J. A., Petersburg, Va.
Collins, John Glenn, Chicago, Ill.
Dannenbaum, H., Philadelphia, Pa.
De Kinder, J. J., Philadelphia, Pa.
Dennis, S. J., Washington, D. C.
Dickerman, Charles, Philadelphia, Pa.
Ely, James, New York, N. Y.
Friedmann, Edward N., New York, N. Y.
Gardenhire, S. M., New York, N. Y.
Graham, Joseph, New York, N. Y.
Gray, C. E., Washington, D. C.
Greene, Van Rensselaer H., New York, N. Y.
Gueth, Oswald, New York, N. Y.
Haire, David E., Philadelphia, Pa.
Hart, B. Franklin, Jr., New York, N. Y.
Haven, Harry M., Boston, Mass.
Herst, Franklin H., Philadelphia, Pa.
Hexamer, W. E., Philadelphia, Pa.
Hoos, William, Philadelphia, Pa.
Hymers, Ewing H., St. Louis, Mo.
Jacobus, D. S., New York, N. Y.
James, T. M., New York, N. Y.
Jensen, Neils, Brooklyn, N. Y.
Jenks, L. Howard, New York, N. Y.
Jones, R. E., Hagerstown, Md.
Judson, H. H., New York, N. Y.
Keller, P. P., Long Branch, N. J.
Laiman, Theo. W., Hartford, Conn.
Langdon, George M., New York, N. Y.
Livezey, John R., Philadelphia, Pa.
Louis, J. S., Cincinnati, Ohio.
Marshall, A. T., Hartford, Conn.
Matthews, F. E., Hartford, Conn.
Maurer, Henry W., Rochester, N. Y.
McGee, H. E., New York, N. Y.
McKee, J. J., Bethlehem, Pa.
Morton, W. P., Philadelphia, Pa.
Morris, O. J., Dallas, Texas.
Newham, H. L., New York, N. Y.
Norwood, Harry Y., Rochester, N. Y.

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Nulsen, H. S., New York, N. Y.
Nusbaum, Lee, Philadelphia, Pa.
Obert, C. W., New York, N. Y.
Ostendorf, William, New York, N. Y.
Parsons, W. Everett, New York, N. Y.
Penney, Edgar, Newburgh, N. Y.
Phillips, E. L., New York, N. Y.
Pilsbry, F. W., Chicago, Ill.
Radcliff, W. H., New York, N. Y.
Robinson, Edward, Burlington, Vt.
Roelker, H. B., New York, N. Y.
Rooksby, E. J., Philadelphia, Pa.
Ross, W. H., New York, N. Y.
Rowe, E. C., Waynesboro, Pa.
Rowe, S. J., New York, N. Y.
Sargent, Allston, New York, N. Y.
Satterthwait, J. J., Wilmington, Del.
Shipley, S. J., New York, N. Y.
Shipley, Thomas, York, Pa.
Shipley, W. S., New York, N. Y.
Shipman, R. L., Ithaca, N. Y.
Spangler, T. C., Newark, N. J.
Sparks, John C., New York, N. Y.
Starr, John E., New York, N. Y.
Sterne, Louis, London, England.
Stevenson, S. P., Chester, Pa.
Stone, Junius H., New York, N. Y.
Strickler, A. B., York, Pa.
Strickler, E. H., New York, N. Y.
Stutz, E., New York, N. Y.
Sutton, William S., New York, N. Y.
Tinker, Edward R., Washington, D. C.
Tinker, H. W., Boston, Mass.
Torrance, Henry, Jr., New York, N. Y.
Tower, Daniel W., Grand Rapids, Mich.
Trowbridge, Amasa, New York, N. Y.
Van Buren, W., New York, N. Y.
Vesterdahl, Karl, New York, N. Y.
Vollmann, C. W., Montreal, Canada.
Voorhees, Gardner T., New York, N. Y.
Wait, John C., New York, N. Y.
Warner, Irving, Wilmington, Del.
Wegemann, Karl, New York, N. Y.
Werliin, L., Philadelphia, Pa.
White, F. H., Montreal, Canada.
Williams, L., Boston, Mass.
Wills, James, New York, N. Y.

THE BANQUET.

The banquet was held in the College Room of The Arena, No. 39 West Thirty-first street, on Tuesday evening, December 4. It was scheduled for 7 o'clock, but it was fully 7:30 before the fifty-seven members and guests were seated.

Vice-President John E. Starr acted as toastmaster in his usual entertaining manner. After speaking of the growth of the Society and the large increase in the attendance at the second annual meeting, as well as at the banquet, he stated that the Society was organized as a national institution, but had already become an international organization, having members in Canada, England, India, Argentine Republic, Australia and New Zealand.

The newly elected president, Professor D. S. Jacobus, was then called on to address the assemblage. President Jacobus told of the importance of the Society and the work it had to do. He further said that the data contained in the papers read before its meetings were of great value to the engineering profession and were not sur-

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passed in importance by those presented in the papers before any other engineering society.

Thomas Shipley in the course of his address stated that the time had passed when the refrigerating engineer could expect to continue in his calling by intimation alone, that he must "make good" or fall to the rear of the ranks. He further said that much was to be expected from the Juniors, and that all the data gathered at the test plant of the York Manufacturing Company would be given to the Society as fast as it was compiled.

Other addresses were made by Vice-President James Wills, S. M. Gardenhire, Robert Mitchell Floyd, C. E. Bonnell, John N. Briggs, O. J. Morris, John C. Sparks, J. J. de Kinder and Henry Torrance, Jr.

The addresses of S. M. Gardenhire and O. J. Morris were notably eloquent.

The benediction was pronounced by President Jacobus.

The following were present at the banquet:

Affleck, W. B., Philadelphia, Pa.
Babcock, W. S., New York, N. Y.
Bates, Guy, Whippany, N. J.
Bilyea, J. T., New York, N. Y.
Bishop, A. C., Detroit, Mich.
Bonnell, C. E., Chicago, Ill.
Bower, W. H., Philadelphia, Pa.
Briggs, J. N., Coeymans, N. Y.
Brownell, C. H.,
Washington Court House, Ohio.
Cary, Albert A., New York, N. Y.
Cole, Harold W., New York, N. Y.
Collins, John Glenn, Chicago, Ill.
De Kinder, J. J., Philadelphia, Pa.
Dennis, S. J., Washington, D. C.
Ely, James, New York, N. Y.
Engel, P. N., Chicago, Ill.
Farish, J. B., New York, N. Y.
Floyd, Robert Mitchell, Boston, Mass.
Gardenhire, S. M., New York, N. Y.
Greene, Van Rensselaer H.,
New York, N. Y.
Herst, Franklin H., Philadelphia, Pa.
Hoos, William, Philadelphia, Pa.
Hymers, Ewing H., St. Louis, Mo.
Jacobus, D. S., New York, N. Y.
Jenks, L. Howard, New York, N. Y.
Jones, R. E., Hagerstown, Md.
Keller, P. P., Long Branch, N. J.
Livezey, John R., Philadelphia, Pa.
Matthews, F. E., Hartford, Conn.
Maurer, Henry W., Rochester, N. Y.
Morris, O. J., Dallas, Texas.
Morton, W. P., Philadelphia, Pa.
Norwood, H. Y., Rochester, N. Y.
Nulsen, Herbert S., New York, N. Y.
Parsons, W. Everett,
New York, N. Y.
Penney, Edgar, Newburgh, N. Y.
Roelker, H. B., New York, N. Y.
Ross, William H., New York, N. Y.
Sargent, Allston, New York, N. Y.
Senner, J. H., New York, N. Y.
Shipley, Thomas, York, Pa.
Shipman, R. L., Ithaca, N. Y.
Smith, Guy B., New York, N. Y.
Sparks, John C., New York, N. Y.
Starr, John E., New York, N. Y.
Stevenson, S. P., Chester, Pa.
Strickler, A. B., York, Pa.
Torrance, Henry, Jr.,
New York, N. Y.
Trowbridge, Amasa,
New York, N. Y.

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Vesterdahl, Karl, New York, N. Y.
Vollmann, C. W., Montreal, Canada.
Voorhees, Gardner T., New York, N. Y.
Wegemann, Karl, New York, N. Y.
Werliin, L., Philadelphia, Pa.
White, F. H., Montreal, Canada.
Wills, James, New York, N. Y.
Wright, Grant, New York, N. Y.

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PAPERS

OF THE

SECOND ANNUAL MEETING

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

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No. 19.

PRESIDENT PARSONS' ADDRESS.

FELLOW MEMBERS OF THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS:

About this time one year ago the first regular annual meeting of The American Society of Refrigerating Engineers was in session. I have occasion to retain in my memory the anxiety which thrust itself upon the several members of the programme committee, who undertook the task of arranging the details of this first meeting, at which it was hoped a general exchange of ideas and knowledge would occur and a general feeling of good fellowship be cultivated and promoted. They felt that the general prosperity and growth of our Society depended largely on the success of this meeting.

Most of you are aware how well they succeeded in preparing an interesting and entertaining programme.

Much praise, however, must be reserved for those who prepared and read papers on the subjects assigned to them, and to all who took part in the discussions. That all of those who worked to arouse at this meeting enthusiasm for the welfare of our Society must have felt amply repaid for all of their trouble can well be imagined.

It was soon discovered that there was no real cause for anxiety lest the meeting should be devoid of life.

After the meeting was over it seemed to be the general verdict that it was a most gratifying success. The somewhat unexpected measure of success was, however, by no means due alone to the efforts of those who had been specially appointed to make preparations for this meeting, but credit was due to every member and every guest in attendance.

Although there were many present whose voices were not heard in the reading of papers or in the discussions which followed, yet everyone present seemed to add an impulse to the general wave of interest and enthusiasm as it swept around and quickly pervaded the atmosphere.

It seemed evident that our Society had been launched at an opportune time, that it had come into existence when the time was ripe for the gathering together of minds that had been for years

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working sometimes along parallel lines, sometimes along diverging lines, sometimes in directly opposite directions, and yet all with kindred objects in view.

Even some of the pioneers in the ice making and refrigerating business seemed glad of this opportunity to get together and compare notes. Those who had fallen into line at a later day—those who were making surveys of the ground which the pioneers originally discovered and explored—realized how much slower the progress is when one attempts to travel entirely alone, without the experience of others as a help.

Even those who are best informed may be able to add to their knowledge every day under ordinary circumstances, but how much more may we all learn by coming into personal contact with a number of minds all bent in the same direction!

But it is not alone for selfish motives that we should unite our efforts for the welfare of this Society—not alone for what we ourselves learn.

We owe a debt for the knowledge which we have appropriated from the experience of those who have worked before us, and some who have worked alongside of us—a debt which we can never pay directly to our benefactors. But this debt stands against us until we pay it in some way to mankind. The least that can be expected of us is to give away for the benefit of others at least an equivalent of what we have received, after we have used it for our gain. But we should do more—we should give back some of the profits also. We should bring our own light from under the bushel, and it is my firm belief that every member of this Society has light—now screened from public view—that, if allowed to shine forth, would do much to enable those who are struggling along the old much-traveled highways to discover the short circuits to improvement and success.

Knowledge is not like a material thing—we may give away any amount of it, and yet retain all we had.

It seems to me that there is no other channel through which such reliable information can be imparted to others as through the agency of a society such as ours.

The information published in our Transactions passes through an ordeal of refining influences and undergoes a keener scrutiny than any similar matter appearing in an ordinary publication could ever receive.

While many of those who are unable to attend our meetings, and those who come after us, following the same branch of engi-

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neering, may be inestimably benefited by the publication of our Transactions, we also who enjoy the privilege of assembling here together and taking part in the proceedings of the Society are sure to be benefited in various ways and to a much greater degree than others.

Nothing could be safer than to assume that every member of this Society has the storehouse of his mind well stocked with useful and valuable information. Most of us, however, are liable to have a certain amount of space occupied by a few fads and fancies, which are likely to be quite upset at one or another of the regular meetings of our Society. But we need someone occasionally to clean away the rubbish for us, that we may have more space to devote to useful purposes.

Our Society, just celebrating its second anniversary, has already attracted widespread attention among those who are interested in refrigeration and ice making. We started as a national society—we are now international.

Our membership has been increased by twenty-eight during the past year, making a total membership of 146.

Since our organization we have had the misfortune to lose two of our members by death.

We have members residing in eighteen States of the Union, three members in Canada, three in the Argentine Republic, two in England, two in Australia, two in New Zealand, and one in India.

We are greatly pleased to have already so many foreign members enrolled with us, and we hope for many more.

We regret, however, that we cannot have the pleasure of welcoming the entire membership of our Society to every regular meeting. We believe, however, that every member will be pleased with and interested in our first volume of the Transactions of the American Society of Refrigerating Engineers, and we believe that many who peruse it carefully and who have failed hitherto to attend our meetings will make a successful effort to be with us when we gather together in the future.

Before closing I wish to express my personal thanks for the assistance which our very efficient secretary has rendered me for the good of the Society during my term of office.

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No. 20.

A FUTURE FOR THE ICE-MANUFACTURING INDUSTRY.

By W. Everett Parsons, New York, N. Y.

(Member of the Society.)

There is usually a very considerable difference between making ice theoretically and conducting an ice-manufacturing business for profit.

It is not my intention, however, to rehearse the causes of failures and disappointments that may have occurred. I would rather seek a place beside those who have discovered the road to success and those who are looking forward to still brighter achievements.

In the first place, an ice-manufacturing business, in order to attain the maximum degree of success, should be managed from its inception by a man who is not only conversant with the management of the ice business in general, but who also understands every detail of the manufacturing process—a man who is capable of choosing the best location, who is capable of planning, at least in outline, the entire layout of the plant; who is competent to choose the very best machinery, apparatus, etc.—not only as a whole, but in every detail, so as to secure the best possible results in every feature of the plant, and who knows how to develop a system by which he can keep informed at all times as to whether every part of the plant is performing its functions up to the maximum degree of efficiency.

Few such men are to be found ready made. They must be made to order. But men will train for such positions just as soon as they realize that they will be suitably compensated according to the results which they are able to produce. As in any other business, the man who can deliver his ice to customers at a less cost than anyone else is master of the situation, from every point of view.

The business must be studied in detail. The site or location of an ice plant affects various items of expense of conducting the business, such as interest on the investment for ground, taxes, assessments, insurance, etc., cost of water supply, cost of delivering fuel to the plant, and of delivering ice to consumers.

I will at this time consider only the use of steam power for operating the ice machines. The steam-producing feature of an ice

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plant can not receive too much careful attention. The cost of fuel is generally looked upon as a most important item in the cost of making ice. Advocates and builders of different types of machinery and different systems of ice making offer as their most attractive claim a certain number of tons of ice which they are supposed to make per ton of coal. But how many of these ice-machine manufacturers are willing to guarantee the heat value of the coal, or the efficiency of the boilers and its accessories, or the efficiency of the firemen, etc? Of course these things can be covered by various assumptions by the ice-machine builders; but that does not help the man who manages an ice plant if he is not able to realize the results which these assumptions call for.

It is better to consider the cost of production of steam as the most important item, and not simply the cost of fuel. Then it becomes a matter of determining the minimum cost of producing a given quantity of steam from and at 212° F., with different kinds and types of boiler-room installations, different kinds and prices of fuel, and different kinds and types of firemen, etc. The cost of production of steam should include every item of expense connected with the boiler room, such as fuel, disposal of ashes, wages of firemen, coal passers, cleaners, etc., cost of water, interest on investment, depreciation, cost of maintenance, taxes, insurance, etc.

Let the costs of operating the different types and makes of ice machines and apparatus be compared in a similar manner to the boiler plant. Charge to the ice machine, not coal, but the heat units it requires from the boiler through the medium of live steam, and credit it with the heat units which it is able to return to the boiler through the medium of exhaust or condensed steam; all per ton of refrigeration, under a given set of conditions.

Treat the auxiliaries in a similar manner and make comparisons of the relative costs of different types and of different methods of operation.

A copious supply of good cold water is of the greatest value to an ice plant and should be secured even at great cost.

The minimum cost of producing a ton of refrigeration with different machines and apparatus and under varying sets of conditions should be determined independently of the systems employed for utilizing this refrigeration for converting water into ice.

The cost of preparing water, by different systems and processes, for freezing should be determined and considered.

We should know the real cost of converting water into merchantable ice by different processes, and in determining the cost

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per ton the weight of ice produced should be determined by means of scales and not left to guesswork.

In every case there is more or less of the ice which has been produced converted back into water during the process of harvesting. This loss varies with the different systems of ice making and should be taken into account accordingly.

The storage of artificial ice furnishes several subjects for controversy. It seems to be the opinion of some that the storage house can be more cheaply refrigerated by means of ice than by mechanical refrigeration. This question should not be difficult to settle.

There is an open field for invention in the line of improved methods and of machinery and appliances that may be used for handling artificial ice cheaply and quickly into and out of storage houses.

The greatest opportunities for improvement are not to be found in the provinces over which the several manufacturers of refrigerating machinery and refrigerating engineers hold special and undisputed sway. They are to be found principally in the production and utilization of steam and in the handling of the ice.

Where conditions and circumstances will permit, ice plants should be established on as large scale as is compatible with a fairly economical delivery system, and they should be operated and managed under the direct supervision of progressive, technically educated engineers specially trained for the purpose.

DISCUSSION.

Henry Torrance, Jr.—I would like to ask whether anyone has figures on the cooling of ice storage houses by refrigeration.

The President—I have no exact figures, but it appears to be a question of whether it is cheaper to produce a ton of refrigeration or a ton of ice.

L. Howard Jenks—It seems to me that this is not exactly the question with can ice. If we melt off 10 per cent. from a block of can ice we have practically destroyed the salability of a 270-pound block. It is not only the loss of 10 per cent. of ice which is melted, but the destruction of the salability of the balance of the cake; so that it becomes really more than the mere question how much this part of the cake of ice costs to produce.

The President—My idea is that after we have once produced the ice it costs less to preserve it by artificial refrigeration than it does to permit it to melt and then make more ice to take its place, whether it is can ice or plate ice or any other kind.

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John E. Starr—There is one point in the question of refrigeration of ice houses versus the melting of the ice which I would like to discuss. I am inclined to agree that the refrigeration would be perhaps cheaper under certain circumstances. It would seem to go without saying that a ton of refrigeration can be produced cheaper than a ton of actual ice, but in an ice house, or any other insulated structure, the amount of heat flowing into the structure through the insulation is proportional to the heat head, or the difference between the outside and the inside temperatures. So, if you hold your ice house at too low a temperature, say 24°, you would begin to reach a point where the economy would balance.

We will assume that the house is 32° inside, and that the outside temperature is, say, 80°, a difference of 48°. Now, assuming that the outside temperature is still 80° and the inside temperature is 24°, a difference of 56°, the flow of heat through the insulation would be in the proportion of 48 to 56, and your refrigerating machine would have to make up the extra quantity. If the temperature was carried still further down you would find that the refrigeration was really more expensive than the melting of the ice.

Edgar Penney—One thing should be taken into account; the refrigerating of ice houses is a matter that throws very little work upon the machine; that is, the machine is not run exclusively for the ice house, so it is very much cheaper to furnish mechanical refrigeration for the ice house, to counteract the incoming heat, than it would be to make new ice.

John E. Starr—It would be true, nevertheless, that it would take so much from the capacity of the ice plant.

The President—I think it would be fair to take the temperature at about 32° to make the comparison with ice. We cannot refrigerate below a temperature of 32° with ice alone.

Edgar Penney—Not below 40°?

The President—With ice stored in the house without refrigeration there will always be melting. The heat comes in and the ice melts. To preserve the ice it should be below 32°.

Edgar Penney—It takes about two tons of refrigeration to make one ton of ice. It will only take one ton of refrigeration to prevent the loss of a ton of ice.

John E. Starr—I think that I stated that at first blush this appears true, but if the temperature of your ice house, with the ice in it, is above 32°, it would only make my contention stronger that under certain circumstances it would take more power to refrigerate than to make the ice otherwise last.

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Edgar Penney—If the ice was melting at 40°, and if you kept it at 32°, you would have a difference of only 8°.

John E. Starr—I have simply drawn attention to the fact that the temperature might be kept too low. I have seen houses that were pretty low down, 20° or 22°. The ordinary practice is to keep the temperature of the houses too low. I am not advocating the system of allowing ice to melt as against refrigeration. I am simply calling attention to what was in my mind, and it is a fact that in a great many places you will find the temperature of the ice houses too low, and the two to one proposition is entirely balanced.

Edgar Penney—You are getting on the commercial end of the question. Now, the delivery of ice in a crisp condition to the customer is of vital importance. Of course, this is a very important end, and when you take ice in the can from an ice tank anywhere from 12° to 18° and put it in the dip tank to thaw it off you have a cake of ice that would average throughout probably in the neighborhood of 20°. This low temperature preserves the ice, and if it is delivered to the customer from the wagon in this condition, there are complaints frequently from the housewife that the ice will not melt, but it is nevertheless good for the domestic trade, which appreciates ice delivered in that crisp condition, and I think it is worth all it costs, if it costs anything at all.

Gardner T. Voorhees—It seems to me, assuming it takes two tons of refrigeration to make a ton of ice, that the proposition would come down to this—that the ice you make not only requires twice as much refrigeration to produce, but also requires a considerable expenditure of money to land it in the ice house. Consequently, the ice in the ice house stands you more than twice as much in cost as it would to make the refrigeration. Further, if the ice house were not refrigerated the ice would melt, and, of course, can ice could not be kept without refrigeration. It would all "go to pot," as the saying is. Also, if the ice stored were refrigerated it should be on account of this leeway of over twice as much in the cost of producing the ice as in the cost of producing the refrigeration, to maintain, as Mr. Starr said, twice the effectiveness. In other words, it would be possible to have the temperature of the ice storage house such that the difference between it and the outside air could be twice as much as it would be without refrigeration and still be ahead of the game.

However, I believe that the great problem in storing ice is not what we have discussed, but the question of whether or not the cost of putting the ice in the house and keeping it, plus any possible

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melting, is less or more than the entire cost of producing ice on the platform, interest on investment, depreciation on plant and building, etc., being considered.

L. Howard Jenks—It seems to me that the fundamental point involved is the passage of heat through the insulation, and therefore the value of the insulation. I know from practical experience in building a large house of 200,000 cubic feet capacity and which contained about 5,000 tons. The ice was held over season and came out in perfect condition, even to the bottom rows. While I have no figures, I know the cost was slight, the insulation being fairly good.

Edgar Penney—I am reminded of a little incident that is irrelevant possibly, but perhaps may be of interest to the members. I put up an ice plant on a tropical island. Curious people came from across the island to get some of the ice. They got about 10 pounds tied up in a bag, and started to carry it home, 10 or 20 miles. When they got there they were disappointed to find the ice melted and angrily came back and nearly murdered our engineer.

The President—I think we would all be much pleased to hear Mr. John N. Briggs express his views on this subject. He has had a great deal of experience in handling ice, and I think it would be interesting to hear from him.

John N. Briggs—I have had some experience in storing ice in large ice houses. We store our ice in the winter and we frequently take it out as late as October with the loss of less than 8 per cent., with no insulation except the sawdust walls around the house, about 24 inches of sawdust, with paper on the outside of the outer wall. My houses are built in this manner: The sawdust is confined between two walls 24 inches apart. I cover the outer skin of the sawdust walls with paper and batten down in the angles and on all joints. The outer sawdust wall is put on the inside of the main posts of the building. Outside of the main posts is a cover of novelty siding. The space between the novelty siding and the outer skin is 12 inches wide, open top and bottom, so that as the sun heats the atmosphere in this space it has a chance to rise and pass out of the top. In houses of this kind we hold our ice from the housing in the winter until October, with a loss oftentimes not exceeding 8 per cent., that is, for wholesale.

Edgar Penney—How long did it take you to empty the ice house after you had opened it?

John N. Briggs—We ship about 300 tons a day and it would take perhaps from eight to nine days to empty a room. After

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housing the ice we protect it with salt hay about 16 inches deep. That is shaken up as lightly as can be done, and it is not tramped upon after we have once put it upon the ice. After we begin shipping we remove the salt hay and do not replace it. The ice is exposed from the time we begin shipping until the room is empty. The room is closed up tight, of course.

I have had a little experience with handling artificial ice. I notice in handling artificial ice that where the ice house is pretty well filled with ice, so that there is little space for air, there is little necessity for refrigerating, but where there is but little ice in the house there is necessity for refrigerating.

I was connected with the American Ice Company and had general charge of the ice house of the plant at Fifty-second Street and East River, New York City. We frequently filled up our ice rooms so that three-quarters of the space was occupied with ice, and when we had a room filled to that extent our meltage was hardly appreciable; but when we had only the floors covered with ice standing on end, as we usually stored it, the meltage would be quite marked, and then the room would have to be refrigerated in order to hold the ice.

R. L. Shipman—Did you have a 36-inch wall in the ice house, 24 inches of sawdust and 12 inches of air space?

John N. Briggs—That is the way in which the houses I speak of are built.

R. L. Shipman—Anything special about the room?

John N. Briggs—No, but over the ice, about 6 feet above the ice, there is a floor of square edge boards with openings perhaps one-eighth of an inch, occasioned by the shrinkage of the boards, and the vapors of the ice have an opportunity to pass through the openings into the hayloft. The loft is ventilated all around, so that as the vapor passes into the loft it goes either way, according to the direction of the wind. In a building 160 by 180 feet there are twenty-six ventilating windows that are 3 by 5 feet. These windows are open perhaps about one-third of their area, so as to admit of the wind blowing through the building from whichever way it may come.

R. L. Shipman—Through the hayloft?

John N. Briggs—Yes. In the top of this building it is always cool in summer. In the top of most natural ice houses you can get a Turkish bath in summer in a few minutes, but by having the ventilation as I have arranged it the lofts are always dry and cool. All

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the hay is placed on the ice after the latter is harvested. When the ice is uncovered the hay is put in the loft.

H. B. Roelker—Do you then shut the windows?

John N. Briggs—No, they are left open. The rooms in the houses that I speak of hold about 2,700 tons, and I have one with sixteen rooms, another with eight, and yet another with ten. The courses of 12-inch ice would average about 80 tons, and we lose from two to three courses in the season—no more than three courses. The rooms are 42 by 78 feet.

Gardner T. Voorhees—I would like to ask Mr. Briggs what kind of a floor is in the house and how it is drained, if it is drained at all.

John N. Briggs—There is no drainage. The earth takes care of all of the water that comes from the ice, as with houses built in this manner there will be little water. Most of the water goes off as vapor and is carried through the ventilating windows. We have little water running through the ice, and it hardly ever affects more than two or three of the top courses. I frequently take out ice within three or four courses of the ground, and find the cakes loose, so that just a little jar of the bars will separate them. We put the ice in at all temperatures, from 40° above to 10° below zero. Of course, the temperature of the ice and the temperature of the room vary as we fill the house.

F. W. Pilsbry—I would like to ask Mr. Briggs what kind of a floor he has?

John N. Briggs—From 4 to 6 inches of sawdust under the board floors.

F. W. Pilsbry—You put a board floor right on the earth?

John N. Briggs—Just a loose board floor, laying the sawdust on the earth. Each room will be opened from six to ten days, according to the rapidity with which we take the ice out.

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No. 21.

THE ALLEN DENSE AIR REFRIGERATING MACHINE.

By H. B. Roelker, New York, N. Y.

(*Member of the Society.*)

The Allen dense air refrigerating machine works on the same mechanical principle as all other practical air refrigerating machines. Air is drawn into a compressor and is compressed; then it is cooled by water and expanded in an engine, which is quite like a steam engine, with an expansion valve. The expansion is arranged so that the pressure at the end of the piston stroke is reduced as near as possible to the starting pressure of compression. Then the reduction of temperature of the air is theoretically equal to the increase by the previous compression. The steam engine, the compressor and the expanding engine are linked to one crank shaft, so that the power of the expansion returns a large portion of the power taken for compression.

The Allen invention was first brought out in 1879 by Leicester Allen, who was the editor of the *American Artisan,* and it was intended to compete with the chemical ice machines then in use. A complicated system of repeated progressive compressions and expansions was used. After a number of different constructions had proved unsatisfactory, the principle now used was adopted. This principle is based on the idea that the machine is to be used only as an auxiliary engine on steam vessels, and possibly in a few places where conditions are similar. Economy of steam consumption is not aimed at in the usual construction any more than in other steam auxiliaries, but rather the greatest possible reliability under all conditions of climate, unskilled attention, and great distance from any sources of supplies. The present machines are so near in their construction and their requirements in regard to attention to the other auxiliaries in the engine room that the oiler takes care of them with the others and little supervision is given by the engineer. The older air ice machines take air of atmospheric pressure from the atmosphere or refrigerated rooms for their medium. The Allen dense air refrigerating machine uses air of considerable pressure

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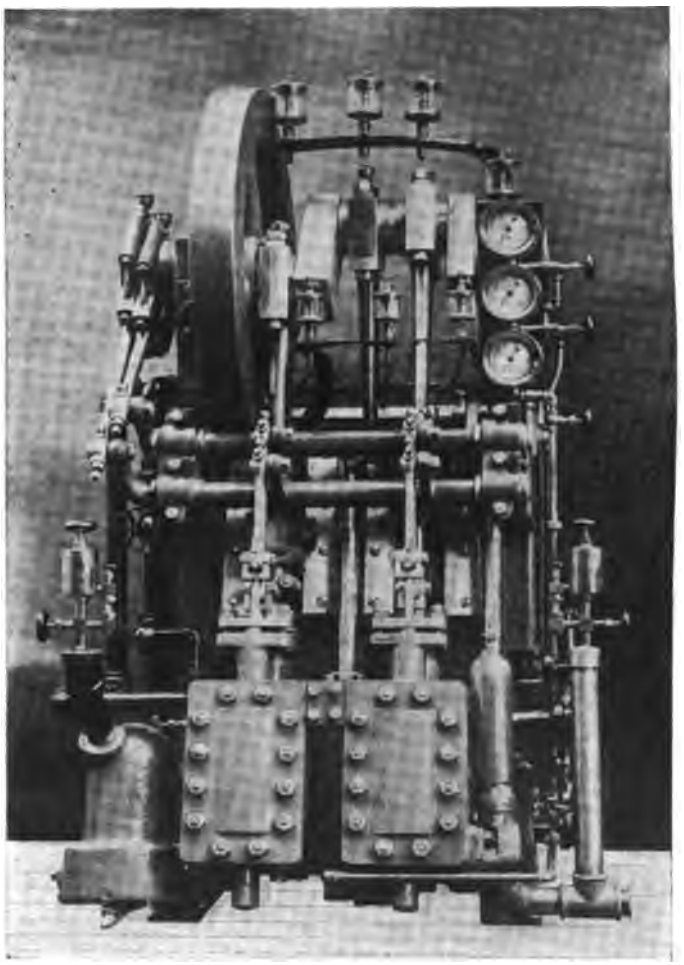

FRONT VIEW OF ALLEN VERTICAL DENSE AIR REFRIGERATING MACHINE.

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and density as the refrigerating medium, which is forced into the compressor for compression, and then expanded back to the original pressure. Hence the designation "dense air" machine. Under the expanded pressure and temperature this air passes into a system of refrigerating and conveying pipes in a similar manner to the chemical medium in chemical machines without brine circulation. The advantage of the system over the machine working from atmospheric pressure consists in the elimination of the effect of the moisture of the atmosphere. The reduction of the vapor to ice means that about 1,200 units of heat per pound of moisture are absorbed and the available cooling effect reduced that much. In tropical seas this moisture amounts to very much more than one generally imagines, and its effect reduces the work of the old refrigerating machines during such conditions to one-half, and frequently to one-third, of that obtained when working in cool air. Those machines therefore have large snow-boxes which must frequently be emptied.

The effective work of a machine is in direct proportion to the weight of air handled, and in the Allen machine a cylinder generally one-sixth or one-eighth the size of the others handles an equal amount of air. This reduces greatly the loss by surface heating. The dense air further presents the great advantage that, owing to the greater amount of cold in a volume and the comparatively smaller friction per unit of weight conveyed, it may be sent through small common steam pipes to far distances in the vessel with very little loss, if only good insulation is employed. The machine is therefore placed in the engine room among the auxiliaries close to the main steam and vacuum pipes, and the cold air is carried to the ice-making box and the meat room and other refrigerated rooms and the closets in the galley and pantry, all of which are generally in the forward part of the vessel, with little loss and great convenience.

The increased efficiency caused by the employment of the dense air as a medium and by the absence of moisture and by the reduced surface heating and friction in the reduced size of machine produces a very much smaller and handier machine, which can conveniently be run at a much greater speed than the older machines.

The pressures commonly employed are 55 to 65 pounds gauge pressure on the expansion side and 225 to 250 pounds on the compression side, making a relation of compression and expansion of from about 3.1 to 3.4 to 1. This gives, under ordinary conditions, to the air entering the expander a practical reduction of temperature of about 105° to 115° F. as it passes into the refrigerating pipes, which shows a loss of about 30 per cent. from the theoretic adiabatic

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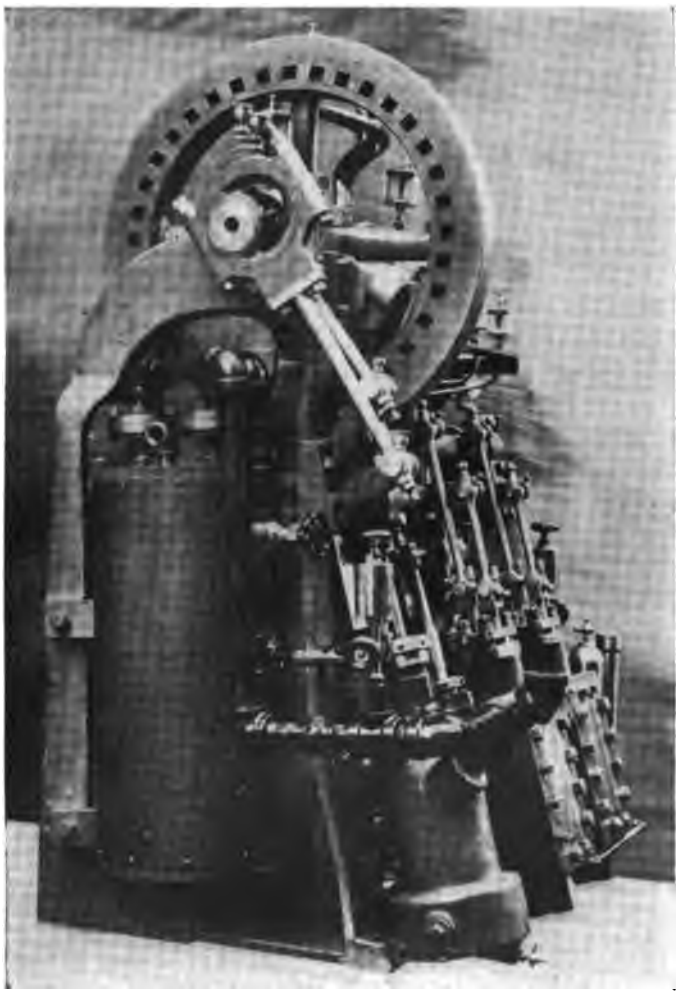

SIDE VIEW OF ALLEN VERTICAL DENSE AIR REFRIGERATING MACHINE.

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reduction by expansion from the higher to the lower pressure. This cold air is then raised in temperature during its passage through the ice-making box and meat room to about 25°, as the meat room is generally kept at 28° to 30°. After that it passes through a room for daily service kept at about 40°, then through a vegetable room kept at about 50°, and often, especially in service on men-of-war, through the large drinking water butts for the crew, where the water coming in from the distillers at frequently 120° is cooled down to about 45° or 50°. So the refrigerating effect of the cold air is utilized commonly through a range of from 50° to about 70° and more.

In many machines a so-called return air cooler or secondary cooler is employed, in which the air, passing out from the meat-room pipes, is passed through a surface cooler, where it comes into surface contact with the compressed air after being cooled by water and further reduces the temperature of the compressed air about 16° to 32°, according to the temperature of the two portions of air; the sea water in tropical places being frequently at 85° and at times 90° and more in harbors and rivers. This increases the useful effect of a machine in the tropics, especially for ice making and meat-house cooling, to nearer that of moderate temperatures. The small apparatus attached to the machine for this purpose gives a temperature change of about 33 per cent. of the degrees difference of the temperatures of the incoming cold air from the meat room and the warm compressed air from the sea-water cooling coil.

In order to have a machine operated with the least personal attention under varying requirements, it is arranged so that it is self-contained. No adjustment of any part but the steam throttle valve is required when the machine is started or stopped or its speed increased or diminished. A very simple circulating water pump is directly attached to the machine and a small air pump of the simplest construction also is attached to the machine, which compresses air from the atmosphere for originally establishing the requisite low pressure and for keeping it up without pressing the stuffing-box packing very tight. This air is passed along a surface cooled by circulating water, the cold of which condenses and deposits the moisture which is at times withdrawn by a petcock.

The compressor valves are a lower and an upper slide valve which at the greatest speeds of the machines produce indicator cards like those compressors produce at slow speed with spring-loaded lifting valves. The expansion cylinder has a lower and an upper slide valve without adjustment for varying the expansion.

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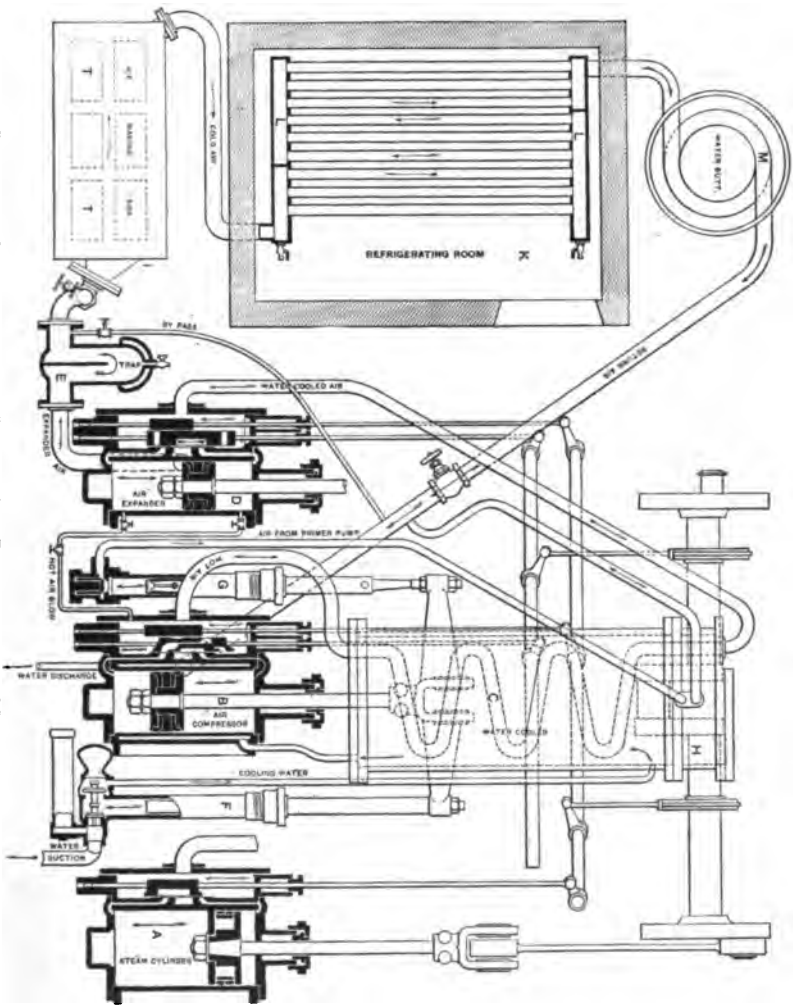

SECTIONAL VIEW OF ALLEN DENSE AIR REFRIGERATING MACHINE.

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The steam engine has a plain slide valve, only the larger machines have expansion valves adjusted by right and left screws. Two eccentrics, each with one rocker shaft, furnish the motion for five or six valve stems. The steam cylinder is large enough so that it will run with a very low steam pressure, as the steam often falls low when ships lie in harbors while the refrigerating machine must never stop. The air cylinders are lubricated by a middling heavy mineral machinery oil which deposits in a trap at the expander outlet and which is withdrawn once a day. This prevents the oil from coating the refrigerating pipes.

If at any time an unusual amount of cold is required, perhaps because warm meat has been taken in and must quickly be chilled, the pressures are increased by tightening the stuffing boxes, and the speed is increased, for which the machines are quite strong enough, requiring then only better attention and more liberal oiling, just as is given to steam engines when running at full power. The speeds then used are from 120 to 200 revolutions per minute, according to the size of the machine, while commonly the speeds are about one-half to two-thirds of these.

The machines are built in various sizes, from one-half to six tons refrigerating power, calculated to be the continuous everyday effect with sea water at a temperature of about 85°.

DISCUSSION.

John E. Starr—I would like to ask—it may have been in the paper, but it was not quite clear to me—if there was any regulator between the compression cylinder and the expansion cylinder, or whether that is not necessary.

H. B. Roelker—There is one definite proportion and there is no regulation of any kind. The English machines have an expansion valve which is regulated, and which is under certain circumstances desirable, because in very hot places they have to cut off shorter and carry higher pressures in order to obtain sufficiently low temperatures to start with. I find that the proportions used in the Allen dense air machines are good enough for common service, and it is entirely unsafe to put any kind of regulating device into the hands of the people who have to take care of the machines. Even in the navy it would all go to pieces and everything would go wrong if we allowed a regulating device of any kind.

The President—Is it usual to install such plants as yours in duplicate on board ship?

H. B. Roelker—They were never used in duplicate until about

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three or four years ago. There are duplicates in some of the new men-o'-war, but in no other vessels.

Gardner T. Voorhees—It would be of great interest to me if I could know what has been the best economy in pounds of steam used per hour in producing one ton of refrigeration. Perhaps that is too leading a question.

H. B. Roelker—It is not known, because everything is calculated for an auxiliary machine, like steam pumps, like the little electric machines and that sort of thing, and I do not know what it would be if the machines were built for economy, in any manner whatever. The machine would have to be built in an entirely different style. It could not be an auxiliary on a vessel, to be taken care of by any fireman or oiler.

Gardner T. Voorhees—Have you ever made any tests of the steam required?

H. B. Roelker—I have not.

John E. Starr—Is there any approximation of the horse power required, irrespective of the efficiency of the steam engine?

H. B. Roelker—Of course I have approximations of what I put in. The power depends much upon the manner in which the machine is used. The machines are of so small measure, all being half-ton, one-ton and two-ton machines, and the largest that we use nowadays being three-ton machines, that it is difficult to quote their efficiencies. A two-ton machine has a capability of, say, 25 horse power, but the machines sometimes run at a great deal more than two tons power. The machine is generally run at seventy-five or eighty revolutions. If necessary it can be run at 150 revolutions and then it would show much more than two tons refrigerating power.

O. J. Morris—What is the size of the steam cylinder and the number of revolutions for the 6-ton refrigerating machine?

H. B. Roelker—The steam cylinder of a 6-ton machine is 12 inches in diameter and 18 inches stroke.

O. J. Morris—I would presume that the average steam pressure would be, say, 100 pounds?

H. B. Roelker—The average would not be more than 30 pounds. You could not use the machine on shipboard differently. The other day there was a test on one of the naval vessels of a 2-ton machine which was built a short time ago. The steam pressure was 32 pounds below the throttle valve. In order to be ready for all emergencies the machine must run under such conditions. A great many of these machines have not stopped during ten years,

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running day and night. A number of vessels in the Philippines, which went there about the time of the Spanish war, have been there ever since. The machines on board have never stopped except for repairs and packing, etc., and frequently the vessels lie in the harbors for weeks and months, and then they carry as little steam as possible. The officers do not want to heat the vessels and they also desire to save the coal.

J. S. Louis—Did I understand you to say that a 2-ton machine required about 25 horse power?

H. B. Roelker—I said we make a steam cylinder large enough to get 25 horse power. By attending to the machine and oiling it liberally and seeing that it does not run hot, that the stuffing boxes are properly oiled, etc., it can be made to do a great deal of work.

L. Williams—Regarding the horse power required to drive cold-air machines, I think that has been gone into carefully and is about three to four times as much as is required for an ammonia machine. A large plant of 600,000 cubic feet was tested in London, the machines being of the old style, taking air from and expanding it directly into the chambers. The outlet temperature from the snow-boxes would be about 110° below zero. I think the air was kept at about 20°. I do not think any secondary coolers were used.

H. B. Roelker—No?

L. Williams—If I remember correctly, it took about three and a half or four times the horse power per ton of refrigeration as is required for the De La Vergne machine.

H. B. Roelker—That is very likely right.

L. Williams—Mr. Roelker's machine is so highly specialized that it scarcely lends itself to discussion, inasmuch as it is almost entirely used in the navy and on steam yachts. In the navy it is used on account of not having any chemicals which might cause an explosion. In the British navy the Hall or Lightfoot machine is used. The size runs from 6 to 8 tons.

The large steamship companies do not use these machines, except the Peninsular and Oriental Steamship Company. They carry large cargoes of meat and use machines as large as 100 tons' capacity which take from 500 to 600 horse power to drive them. They carry meat as low as 10° below zero, and have no difficulty with the machines, which take up more space, are heavier and much less efficient than carbonic acid or ammonia machines, but are preferred by these companies because they use air only.

H. B. Roelker—They can get these low temperatures by the air better than by chemicals.

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L. Williams—That is so, but there are six lines trading in the East that use ammonia entirely. On the other hand, the White Star Line, which has vessels carrying large cargoes, uses carbonic acid. Apparently every shipping company has its own special preference.

As to the difference in the two systems, where the air comes back from the pipes one great advantage appears to me to be that the trouble of icing up the expansion valves is saved entirely. That is the chief cause of trouble with the old machines. The air is expanded and is very dry, so that it will dry even a frozen carcass of mutton, and pick up moisture. There is a great deal of trouble with some of the machines on account of the freezing up of the expansion valves. The Lightfoot machine is arranged to avoid this. The Haslem machine has an expansion valve. The Lightfoot has not got a trick cut-off; it has merely a rolling valve and the eccentric rod is fitted with a knuckle and a screw to adjust the cut-off, and no trouble is had with ice on the ports because of the very quick exhaust of the machine. The air shoots right into a large ice box and ice cannot lodge on the valve on account of its shape.

H. B. Roelker—The air machine is used because there is a fear that something might spoil on account of the ammonia on board. A pipe might burst and then the meat would spoil.

L. Williams—The ammonia does not come in contact with the meat.

H. B. Roelker—That is probably true, but there has been trouble of that kind.

L. Williams—There is only one British company that does not use brine pipes and in this case the ammonia pipes come in contact with the cargoes. The boats are very large and carry from 110,000 to 140,000 carcasses of mutton. The whole ship is often refrigerated and has duplicate coolers. The air is taken in at the bottom of the ship and goes out at her side and top. Mr. Roelker's machine produces dry air, but as an offset he places pipes throughout the cargo space.

In the British navy the ice box is usually outside the cooling room. Inside of that room is built a little air box and some molds are dropped in to make can ice. The air shoots over the ice cans at about 110° below zero before going into the room and can ice is made in that way.

H. B. Roelker—We have a special ice-making box for that purpose which is placed where it is convenient. There is a certain amount of expense connected with the pipes, but one great trouble

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with the other ice machines is that the air gets into the room and dries the meat, which is then not worth so much.

L. Williams—The air dries everything. There is an advantage in the storing of goods for long distances.

H. B. Roelker—There is the greatest trouble with an air system of that kind; it dries out the meat so much that it is worth a great deal less money than it would otherwise be.

L. Williams—The Japanese navy, the French navy, and I think the German navy, use carbonic acid machines.

H. B. Roelker—Most of them use carbonic acid machines at present.

L. Williams—You obtain all of the advantages of the carbonic acid machines except efficiency, but you also get some disadvantages.

H. B. Roelker—In all of the world's navies there is the same requirement as there is in the United States, that everything that goes into a man-o'-war must be built in the country, and if that is not done the navy does not get any appropriation; this is the case in Germany, England and France.

L. Williams—It does not apply to England. Very few English vessels are fitted with carbonic acid machines, and England may be called the home of the carbonic acid machines, inasmuch as they were first developed there. There is no efficient English carbonic acid machine except Hall's, which I know to be efficient. It will do good work and it gives very little trouble in operation. We have fifteen vessels fitted with machines of 75 to 90 tons of carbonic acid capacity, and they all do very fine work. With me it is an open question whether I use ammonia or carbonic acid. It depends upon where the ship is going and when the machinery is to be placed in her.

H. B. Roelker—I have generally been told that the efficiency of the carbonic acid machines deteriorates in hot climates.

L. Williams—It does because it is an auxiliary. You cannot measure the steam consumption. We do not take the trouble to indicate it, to see what power it does take.

H. B. Roelker—You could not measure the steam anyway.

L. Williams—Our engine horse power is about 3,000 on the ships used in the banana trade and the efficiency of a 120-horse power machine is therefore not of great importance as a factor of the whole.

H. B. Roelker—You do not care in carrying bananas whether the temperature gets up to 50° or 55°.

L. Williams—If the goods come in slowly they are generally

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cooled down at once. On bananas we load 1,200 tons of fruit in twelve hours. That fruit comes in at an average temperature of 90° to 98°, and if that cargo is not cooled off within three days down to 56° a loss of about $12,000 can be figured on when it arrives. We do not have to deal with low temperatures, but have to contend with an excessive amount of refrigeration. We have ships running to England as well.

All our work is done in the tropics. For instance, we load a ship in Costa Rica. The average temperature of sea water will be about 86°, say 84° to 86°. The ship takes two days and a half to go to Jamaica, and is all the time in waters varying from 86° to about 80°, which drops to about 78°, and then after leaving Jamaica she runs into the Gulf Stream and back into the eighties. The cargo has then been cooled down as low as required, and the machines are running dead slow, as it is only necessary to take up the loss through the insulation and heating tendency of the fruit.

H. B. Roelker—The carbonic acid machine is used in connection with a blower?

L. Williams—We run brine through brine coils and circulate the air over the coils by blowers.

H. B. Roelker—You blow the air through the coils and then into the fruit.

L. Williams—We never go below 28° with our brine.

H. B. Roelker—What capacity of machines do you use?

L. Williams—The smallest machines are 54 tons and the largest 90 tons of refrigeration.

H. B. Roelker—It would be foolish for anyone to use our machines for large work.

L. Williams—The power required to drive them would be very great, and the weight would be prohibitive; in fact, I do not know how it could be done.

H. B. Roelker—It could be done, but it pays better to have engineers who can take care of the chemical machines.

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No. 22.

EXPERIMENTS WITH BINARY REFRIGERATION.

By Edgar Penney, Newburgh, N. Y.

(Member of the Society.)

Accepted scientific authorities claim that a mixture of two or more volatile liquids in a mechanical refrigerating machine or apparatus possesses distinct economic advantages over a single liquid.

Several patents covering the use of refrigerating compounds of two or more volatile liquids or gases have been granted in the United State, and it appears from a pamphlet issued in 1880 by C. H. Delamater & Co., of New York City, that they advertised machines called the "binary absorption system." The Delamater prospectus asserted that the firm "had overcome the intense pressure of stronger gases, such as ammonia and carbonic acid, etc., besides removing various other defects incident to the use of a single gas," and described the operation as "that one gas had such an affinity or capacity of absorption for the other in the condenser that working pressures were reduced to a point lower than that produced by a single gas when used separately; and that when expanded into the refrigerator intense cold was produced for a small amount of power expended." In other words, the claim was made that the absorption of one gas by another in a condenser would reduce the working pressure of liquefaction with a given temperature of condensing water, and that when expanded in a refrigerator the two or more constituents would separate, each taking up heat according to its original capacity. Also that after evaporation, when passed through the compressor and returned to the condenser, the least volatile gas was liquefied first, and immediately proceeded to reabsorb the other or higher pressure gas, thus lowering the pressure. The exact phrase used was "liquefying it by an affinity of absorption." The binary used by C. H. Delamater & Co. was patented by Du Motay and Rossi, chemists and engineers, and consisted of sulphur dioxide and carbon dioxide, the exact proportions of which were not given. A paper on the "binary absorption system" was read before the American Society of Mechanical Engineers in 1881 by H. F. J. Porter.

So far as the writer has been able to ascertain, the conclusions reached by the scientific authorities, chemists and engineers, as to the efficiency of binary gases in refrigeration, were based on theoretical

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and mathematical deductions, supported only by laboratory experiments, which showed that when two suitable gases in various proportions were kept in contact for a considerable period in closed vessels—as, for instance, when soda-water bottles, with their binary contents, were subjected to a range of temperatures by immersion in freezing mixtures for low temperatures and heated water for the higher temperatures—one gas continued to absorb the other to the point of full saturation. From gauges attached to the vessels, pressures were obtained corresponding to each temperature and mixture and a curve prepared such as shown in Fig. 1, which represents the results of several experiments made by Rossi. This figure also shows for comparison the curves for ammonia and sulphur dioxide, and in the upper left-hand corner a small portion of the curve for carbon dioxide. These laboratory experiments were conducted in 1897.

In 1885 experiments were conducted in Geneva by Prof. Albert Rilliet, upon request of Theodore Turrettini, the engineer, to determine the tensions of vapor which are obtained in making mixtures of sulphur dioxide in a liquid state and of carbonic acid, and submitting these mixtures to different temperatures. In these experiments two reservoirs made of forged iron were used, forming two parts connected, but arranged so that the vessels were detachable one from the other, a stopcock being placed between the inlet and outlet of each. Let the two reservoirs be called A and B. A known quantity of liquid was introduced into A, as, for instance, sulphur dioxide; the reservoir B contained carbonic acid. The pressures for each temperature condition were noted by gauges attached to each vessel. By manipulating the intermediate stopcock a small quantity of carbonic acid in the gaseous state was made to pass into the receptacle containing sulphur dioxide. The pressure in A necessarily rose in proportion to the carbonic acid introduced, but soon, by the effect of the absorption of the carbonic acid by the sulphur dioxide, the pressures fell and reached a point where agitation of the vessel by hand showed no change at that temperature, when the pressures for the various percentages by weight of mixtures were taken. The conclusions reached were:

"First, the tension of vapors in a saturated mixture of carbonic acid and sulphur dioxide in a liquid state in proportion to their molecular weight is less than 20 atmospheres at the temperature of +20° F.

"Second, that the introduction of a small quantity of carbonic acid in a gaseous state (less than 1 per cent.) in the liquid sulphur dioxide modifies sensibly the tensions of the vapor of this last and

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lowers the boiling point about 10° C. The curve of the pressure of the mixture thus obtained does not appear to cut that of the pure sulphur dioxide."

Rossi's experiment of a similar nature indicated that as a general result, when the binary fluid contained 20 per cent. or thereabouts of carbon dioxide, it showed a point of ebullition from 5° to 10° F. below that of ammonia; while at 80° its pressures were from 34 to 40 pounds per square inch below those of ammonia at the same temperature (110 pounds against 144 to 150 pounds). On the other hand, while at zero centigrade, the extreme temperature considered proper to maintain in a refrigerator when making ice in a machine, the pressure of ammonia is 15 pounds, that of the binary is 28 pounds, which gives a ratio of absolute pressures of nearly 43 to 30, which is equivalent to 1.43. This was claimed to be an advantage in favor of the binary fluid, since there was an increase in proportion of the weight of the gas entering a pump of a given capacity and it was concluded *a priori* that this liquid would show great advantages over ammonia.

Following are extracts from a report made by Henry B. Mott, Ph.D., LL.D., chemist and engineer, in 1896 on binary compounds:

"Experiments on a large scale have demonstrated that the binary compound (carbon dioxide and sulphur dioxide) when used in properly constructed ice machines, like many now in use, will produce 180 pounds of ice with the same expenditure of fuel as is required to produce 125 pounds of ice when liquefied ammonia is used, and when the temperature is 90° F. this binary will exercise a pressure to the square inch of at least 80 pounds less than that exercised by ammonia.

"The two constituents selected for the production of the binary compound are capable of combining into one substance in the condenser, and at the same time liberate heat units, an equivalent amount of which being absorbed in a refrigerator thus augments the machine in two directions.

"The two constituents used possess efficient cold-producing qualities when used separately, and when united in the formation of the binary furnish a liquid possessing materially less pressure than exercised by the constituents used separately, thus showing that they have combined in the formation of a compound and do not exist as a mere mixture.

"The fact that the binary compound can be utilized at so low a pressure insures the use of much less water for cooling purposes, etc."

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The quotations show what the men of high standing professionally assert after mathematical and laboratory investigations, some of them claiming that the theory put in practice would show a saving of from 36 to 69 per cent.

Experiments conducted by Schroter show practically equal efficiencies for ammonia and the binary compound. The writer would note at this point that there appeared to be other scientific men who claimed that there was no gain by the use of the binary, as it abrogated the operation of the second law of thermodynamics, as applied to refrigeration, asserting that to raise a given amount of heat from a certain refrigerator level of temperature to the condenser level of temperature the work done is in proportion to the lift; or, in other words, that something cannot be done for nothing.

In all the laboratory experiments referred to the circulating or working conditions under which the liquid binary would be operated in an actual refrigerating machine were conspicuous by their absence; the chemist allowed plenty of time for the liquids to cool and assimilate, while the refrigerating machine gives but little time and rushes the gases through single file when performing their cycle. On Rossi's chart, Fig. 1, the curves established were assumed to represent, in so far as their pressure and temperature conditions were concerned, a gain in favor of the binary over sulphur dioxide or ammonia in the actual work of a refrigerating apparatus for a certain amount of power expended, this gain being entirely due to the action or affinity or power of absorption of the sulphur dioxide for carbon dioxide, and it was also asserted that several gases could be mixed in such varying proportions that results equal to any single gas could be paralleled and its working pressure duplicated. It was also claimed that a mixture of sulphur dioxide and carbon dioxide could be produced which would equal, in the same machine, ammonia in refrigerating effect, but with a great reduction of pressure.

The tests which form the subject of this paper were made to prove or disprove the claim of the advocates of binary liquids in refrigerating machines, and for this purpose a 10-ton commercial ammonia compression apparatus especially equipped for experimental work was used. The general layout of the equipment is shown by the erecting plan, Fig. 2. The compressor was horizontal, double-acting, of 6½-inch bore and 12-inch stroke, having water-jacketed heads and cylinder body. The mechanical details of the pump are shown in Fig. 3. Absence of clearance space in this compressor is noticeable. The steam engine driving the compressor was of the plain slide valve throttle governor type, with 10-inch bore and 12-inch

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stroke. The submerged condenser, Fig. 4, contained 840 lineal feet of 1-inch pipe in eight coils placed in a tank 12 feet long, 4 feet wide and 5 feet high. The refrigerator or brine tank, Fig. 5, was insulated with 15 inches of sawdust and several layers of waterproof paper with wood sheathing, and contained ten coils, equal to 1,680 lineal feet of 1-inch pipe. The tank was 14 feet long, 5 feet wide and 5 feet high. With brine at 12° F. the radiation loss in eighteen hours was 2° F.

A brine heating box of suitable size, with heating coils provided with a baffle partition, was used for absorbing the refrigeration produced. The brine circulating pump was a Worthington duplex, having 5¼-inch steam cylinder, 4-inch brine cylinder and 5-inch stroke.

Worthington standard meters were used for measuring the brine. A special meter from the Stevens Institute of Technology was used for measuring the liquid passing from the condenser to the expansion valve. The liquid receiver was also mounted on a scale.

Standard and calibrated thermometers were used as follows:

Gas discharge	+32° to 400° F.
Gas suction	—40° to +70° F.
Expansion header	—70° to +70° F.
Liquid from condenser	—10° to +100° F.
Brine from tank	—40° to +70° F.
Brine from heater	—40° to +70° F.
Water to condenser	+10° to +100° F.
Water from condenser	+10° to +100° F.
Jacket water inlet	—10° to +150° F.
Jacket water outlet	—10° to +150° F.
Six water thermometers	0° to +212° F.
Two atmospheric thermometers	+10° to +130° F.
Two steam thermometers	200° to 400° F.

Two Baumé scales (light), two Baumé scales (heavy), two steam-pressure gauges, 100 pounds; two pressure gauges, ammonia suction, combined pressure and vacuum; two pressure gauges, ammonia discharge, combined pressure and vacuum; two water-pressure gauges, 100 pounds; three steam-pressure gauges, 150 pounds; revolution counters, steam traps for heater box, six weighing scales, four oxide or binary pressure gauges, combined pressure and vacuum; indicators for compressor, steam cylinder, suction and discharge gas pipe; steam calorimeter, and other instruments were used as required.

The locations of most of these instruments are shown in Fig. 2.

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They are simply mentioned here to show what preparations were made for the test.

The initial tests, Nos. 1, 2, 3 and 4, made December 1, 3 and 4, 1897, were run with ammonia for the purpose of demonstrating the refrigerating capacity of the machine with this agent.

Tests Nos. 5 and 6, run December 8 to 11, 1897, were made with pure anhydrous sulphur dioxide; test No. 7, December 11 to 16, 1897, with binary compound (carbon dioxide, 7½ pounds, sulphur dioxide, 200 pounds); test No. 8 with binary compound (carbon dioxide, 17½ pounds, sulphur dioxide, 225 pounds), and test No. 9 with binary compound (carbon dioxide, 23½ pounds, sulphur dioxide, 305 pounds).

Final experiments were made with mixtures containing as high as 20 per cent. of carbon dioxide. Typical indicator diagrams from each test are shown herewith.

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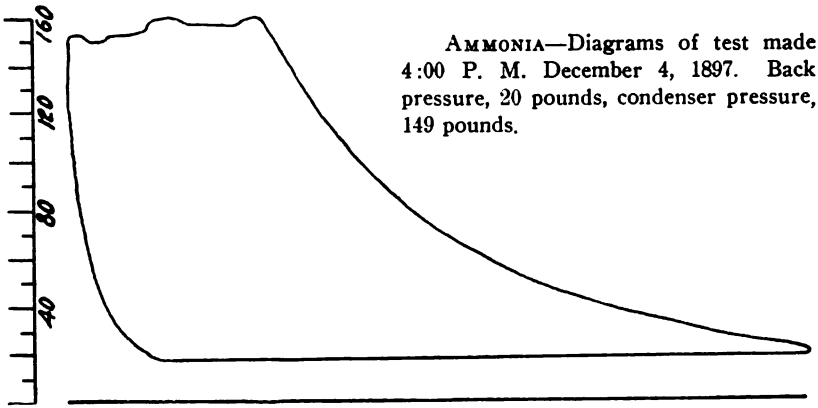
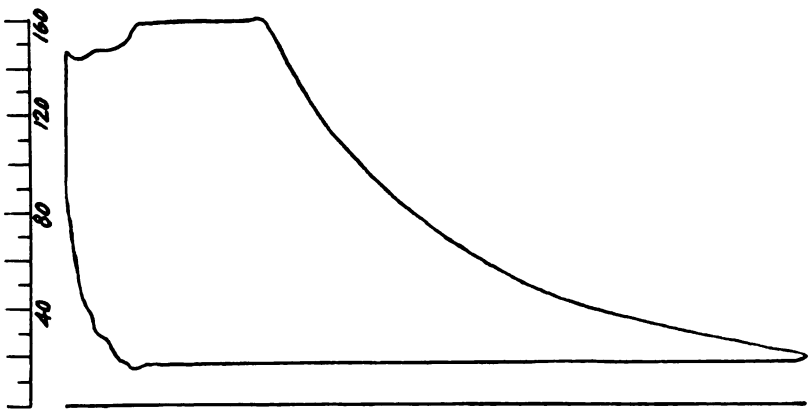
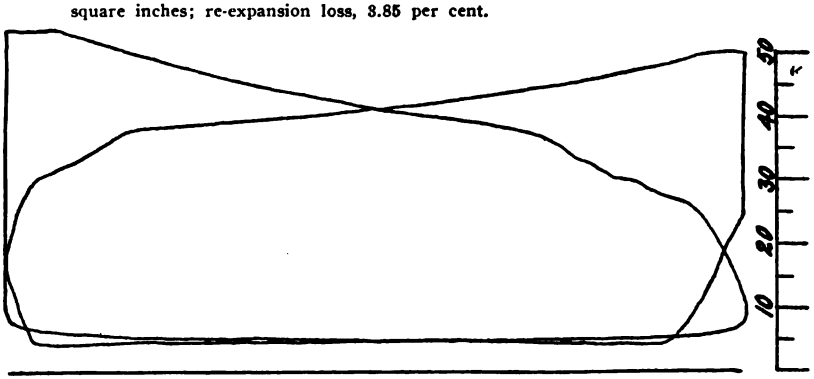


AMMONIA—Diagrams of test made 4:00 P. M. December 4, 1897. Back pressure, 20 pounds, condenser pressure, 149 pounds.

Front end of compressor: Scale, 80; M. E. P., 65.5 pounds; area, 3.19 square inches; re-expansion loss, 3.9 per cent.



Back end of compressor: Scale, 80; M. E. P., 68.2 pounds; area, 3.32 square inches; re-expansion loss, 3.85 per cent.



Steam engine: Scale, 30; revolutions, 101 per minute; steam pressure, 76 pounds; M. E. P., 34.27 pounds.

Left-hand card: M. E. P., 35.04 pounds; area, 4.5 square inches; re-expansion loss, 3.85 per cent.

Right-hand card: M. E. P., 33.5 pounds; area, 4.43 square inches; re-expansion loss, 3.85 per cent.

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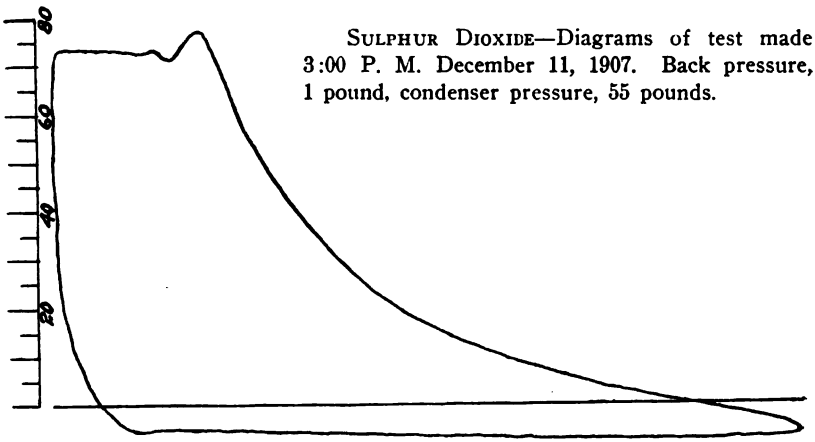
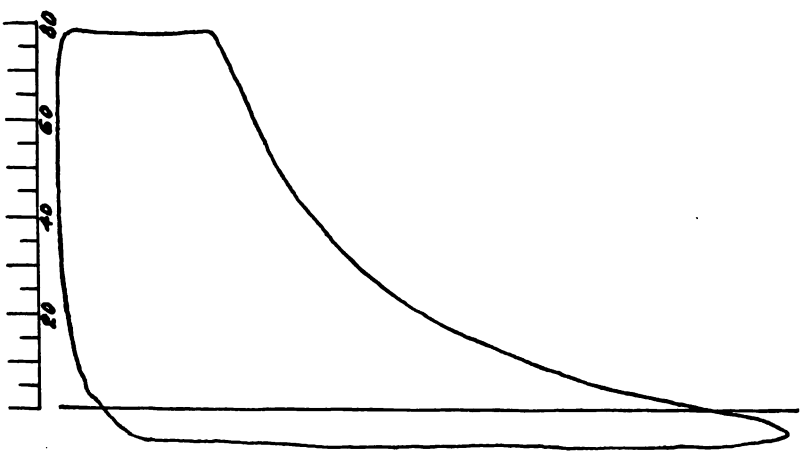
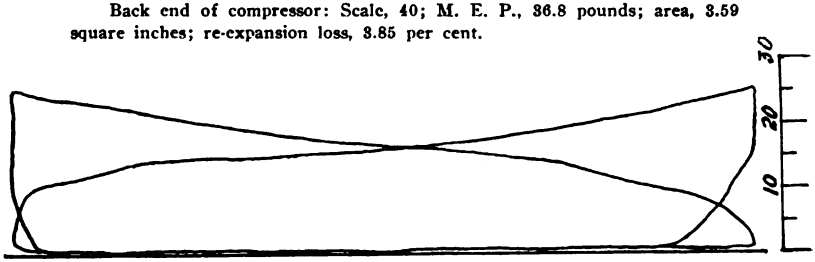


SULPHUR DIOXIDE—Diagrams of test made 3:00 P. M. December 11, 1907. Back pressure, 1 pound, condenser pressure, 55 pounds.

Front end of compressor: Scale, 40; M. E. P., 33.8 pounds; area, 3.3 square inches; re-expansion loss, 3.9 per cent.



Back end of compressor: Scale, 40; M. E. P., 36.8 pounds; area, 3.59 square inches; re-expansion loss, 3.85 per cent.



Steam engine: Scale, 30; revolutions, 115 per minute; steam pressure, 75 pounds; M. E. P., 16.15 pounds.

Left-hand card: M. E. P., 15.57 pounds; area, 2.02 square inches; re-expansion loss, 3.85 per cent.

Right-hand card: M. E. P., 16.74 pounds; area, 2.0 square inches; re-expansion loss, 3.85 per cent.

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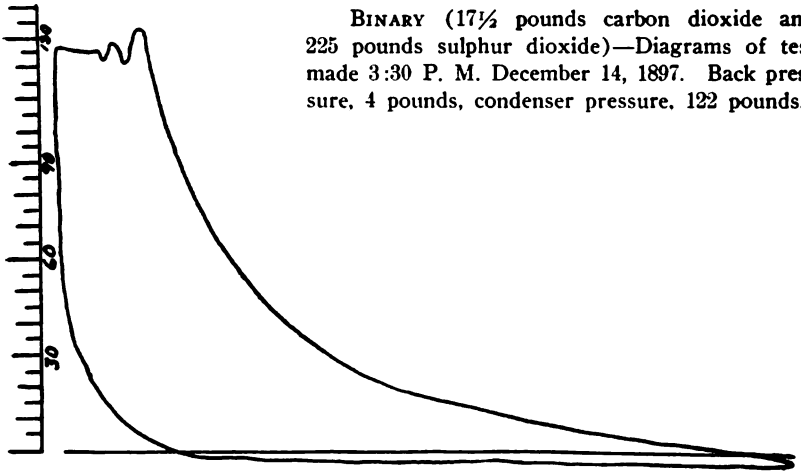
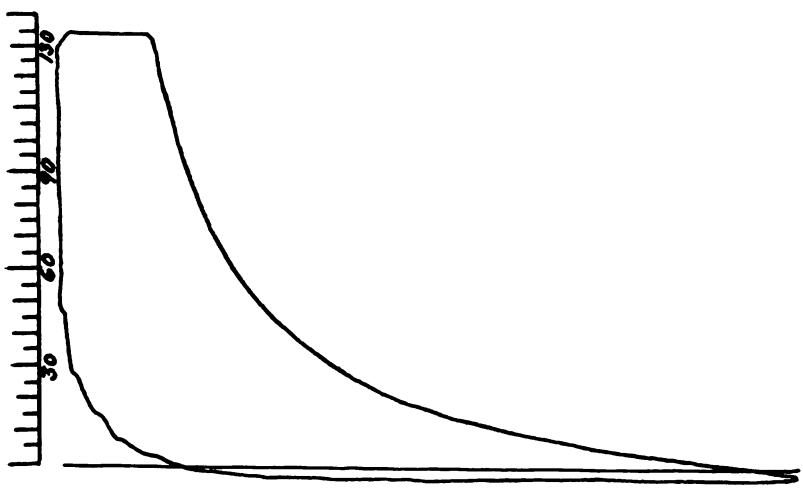
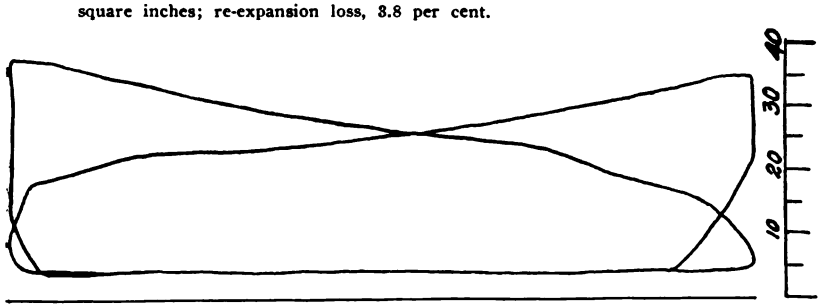


BINARY (17½ pounds carbon dioxide and 225 pounds sulphur dioxide)—Diagrams of test made 3:30 P. M. December 14, 1897. Back pressure, 4 pounds, condenser pressure, 122 pounds.

Front end of compressor: Scale, 60; M. E. P., 36.9 pounds; area, 2.34 square inches; re-expansion loss, 3.8 per cent.



Back end of compressor: Scale, 60; M. E. P., 39.36 pounds; area, 2.5 square inches; re-expansion loss, 3.8 per cent.



Steam engine: Scale, 30; revolutions, 116 per minute; steam pressure, 75 pounds; M. E. P., 21.4 pounds.

Left-hand card: M. E. P., 21.92 pounds; area, 2.82 square inches; re-expansion loss, 3.85 per cent.

Right-hand card: M. E. P., 20.88 pounds; area, 2.68 square inches; re-expansion loss, 3.85 per cent.

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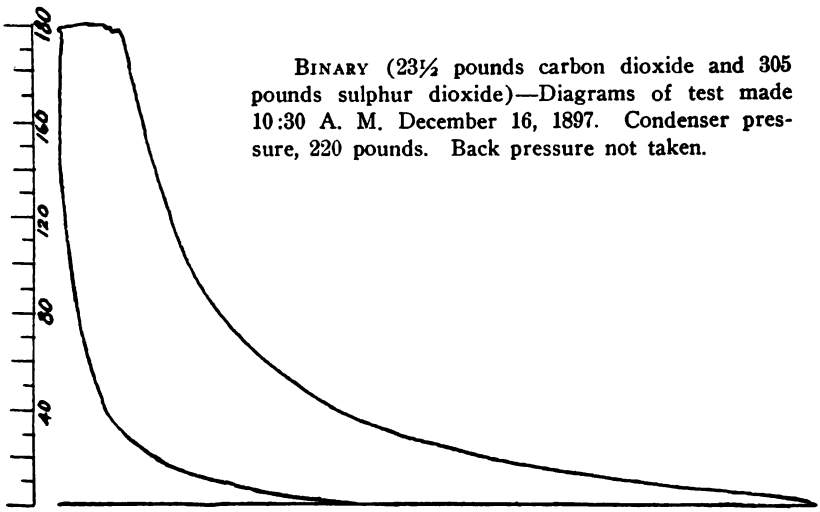
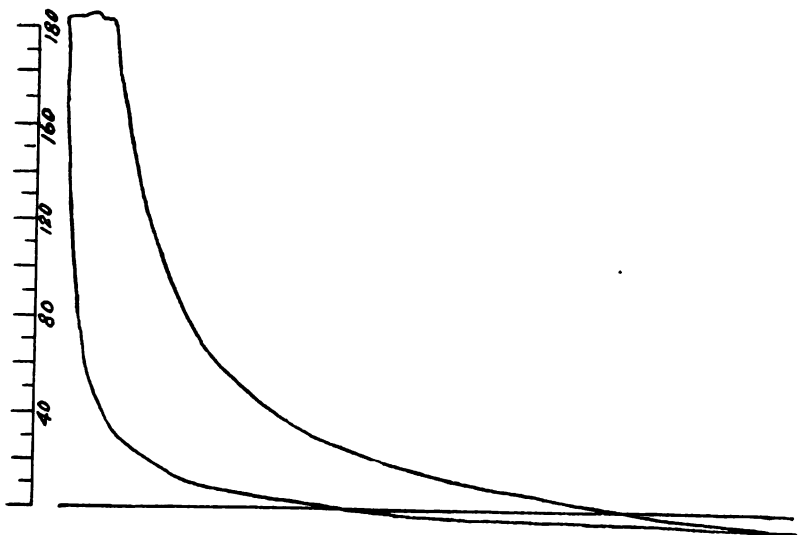
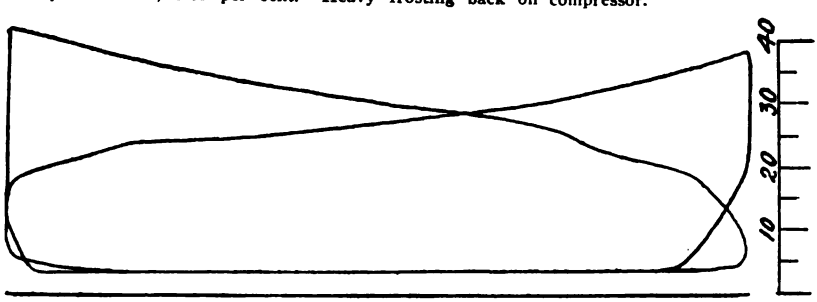


BINARY (23½ pounds carbon dioxide and 305 pounds sulphur dioxide)—Diagrams of test made 10:30 A. M. December 16, 1897. Condenser pressure, 220 pounds. Back pressure not taken.

Front end of compressor: Scale, 80; M. E. P., 42.6 pounds; area, 2.08 square inches; re-expansion loss, 3.9 per cent. Heavy frosting back on compressor.



Back end of compressor: Scale, 80; M. E. P., 34.4 pounds; area, 1.65 square inches; re-expansion loss, 3.85 per cent. Heavy frosting back on compressor.



Steam engine: Scale, 30; revolutions, 115 per minute; steam pressure, 75 pounds; M. E. P., 24.29 pounds.

Left-hand card: M. E. P., 25.65 pounds; area, 3.25 square inches; re-expansion loss, 3.8 per cent.

Right-hand card: M. E. P., 22.94 pounds; area, 2.92 square inches; re-expansion loss, 3.8 per cent.

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TABLE I.—COMPARATIVE WORK AND POWER.

Date.	Time.	Number of Card.	Compressor. Revolutions.	Compressor. M. E. P.	Steam Cyl. M. E. P.	Steam Cyl. I. H. P.	Comparative Work Per Min.	Ratio of Comparative Work to I. H. P.	Degrees Cooled.	Tons of Refrigeration.
AMMONIA.										
Dec. 1, 1897..	7:30 a. m.	11	100	58.20	29.79	14.18	20.24	1.425	5	5.70
Dec. 3, 1897..	9:00 p. m.	8	100	58.20	28.71	13.64	19.55	1.433	5	6.44
Dec. 4, 1897..	4:00 p. m.	6	101	66.85	34.27	16.27	35.95	2.209	5	10.84
SULPHUR DIOXIDE.										
Dec. 8, 1897..	4:45 p. m.	5	101	50.26	30.66	14.52	8.03	0.552	3.5	2.37
Dec. 11, 1897.	3:00 p. m.	10	115	35.3	16.15	9.00	13.62	1.513	4.17	4.02
BINARY.										
Carbon Dioxide, 7½ pounds—Sulphur Dioxide, 200 pounds.										
Dec. 11, 1897.	10:30 p. m.	M	116	33.60	17.32	9.56	12.64	1.322	5	3.73
Carbon Dioxide, 17½ pounds—Sulphur Dioxide, 225 pounds.										
Dec. 13, 1897.	5:30 p. m.	6	116	29.07	19.03	10.70	12.72	1.188	5	3.76
Dec. 14, 1897.	3:30 p. m.	D	116	38.13	21.42	12.08	12.83	1.062	5	3.79
Dec. 15, 1897.	3:00 p. m.	5	116	34.99	18.86	10.60	12.39	1.168	5	3.65
Carbon Dioxide, 23½ pounds—Sulphur Dioxide, 305 pounds.										
Dec. 15, 1897.	3:30 p. m.	A	116	32.66	18.61	10.58	11.33	1.072	5	3.39
Dec. 15, 1897.	6:00 p. m.	F	116	49.15	27.83	15.85	8.88	0.560	5	2.62
Dec. 16, 1897,	10:30 a. m.	2	115	38.5	24.29	13.70	9.28	0.677	5	2.73
SPEED OF COMPRESSOR CHANGED TO 85 REVOLUTIONS.										
Dec. 16, 1897.	12:30 p. m.	6	85	33.55	20.91	8.44	13.00	1.540	5	3.59
Dec. 16, 1897.	2:00 p. m.	9	85	46.00	21.50	8.68	9.15	1.054	5	2.71

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Table I shows the comparative amount of refrigeration and power for each combination. The efficiencies are proportional to the figures given in the column headed "Ratio of Comparative Work to Indicated Horse Power." The figures given in Table I were not determined by an exhaustive computation of all of the several hundred diagrams, measurements and data taken during the tests, but rather by selecting a few of the indicator diagrams, brine qualities and temperatures which visually represented on inspection fairly good averages for the tests.

Inasmuch as tests were undertaken to determine the practical efficiency of the binary compound (carbon dioxide and sulphur dioxide) compared with the single refrigerants sulphur dioxide and ammonia, and their commercial value in an ordinary refrigerating machine, the results reached early in the experiments made their continuance and further expense unnecessary.

The data collected during the tests are available for analysis by those who may be interested. Complete calculations were not made at the time of the tests and have not been made since because time could not be spared by the writer, who has therefore not attempted to do more than give a general description.

In general, the claims of superiority of a binary compound to produce a greater refrigerating effect with the same amount of work and cooling water put into a practical refrigerating machine are shown by actual tests to be purely theoretical and imaginary, and the recognized laws governing such operation still remain unshaken.

Rossi, the patentee of the binary compound, investigated the experimental plant described in this paper, and reported in part as follows:

First, that the plant, one of the ammonia type, of a rated capacity of 10 tons refrigeration, has proved from tests made with ammonia to come up to this capacity.

Second, that the same plant charged with sulphur dioxide alone gave a production in cold less than that of ammonia, as it should give, but in the usual proportions of production in cold by sulphur dioxide as compared with that produced by ammonia for same diameter of pump and velocity of piston.

Third, that the same plant charged with a liquid containing 100 pounds of sulphur dioxide and 20 pounds of carbon dioxide gave erratic and unpractical results.

Fourth, that several tests made with the binary refrigerant containing different percentages of carbon dioxide (4 to 8 pounds carbon

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dioxide to 100 pounds sulphur dioxide) did not give better results than sulphur dioxide used alone.

Fifth, as stated by Mr. Penney, from observations made by him with an 8 per cent. saturation (8 pounds of carbon dioxide and 100 pounds of sulphur dioxide), the conditions of running the machine were a pressure on the expander, as the liquid returns from the condenser to the refrigerator, of 2 pounds per square inch, the temperature at this point being —14° F., and even reaching below. With a 20 per cent. carbon dioxide liquid the mercury in which the thermometer was dipped froze solid. With ammonia at the same point (return valve for liquid from condenser to refrigerator) the temperature was about +13° F. and the pressure 20 pounds. The pressure of gas in the condenser was 105 pounds, more or less.

"In short, the machine did not show any better results with the binary than with sulphur dioxide. We are then in this dilemma:

"(*a*) Either really the liquid cannot produce any more than it has actually done in the tests, or (*b*) the machine well adapted for the use of ammonia and even sulphur dioxide, both simple liquids, proved to be inefficient for the use of a binary liquid to the best advantage, if really the binary has any superiority over sulphur dioxide.

"Further experiments involving important changes in the machine will prove costly, and, after all, may not produce better results, and persons financially interested in such matters should be honestly forewarned of these chances of failure, let it be a complete or partial one.

"Changing the plant, even only to the extent of using a larger gas pump and modifying certain parts, as far as practicable, involves an outlay of money apparently not justified. I offer some suggestions which do not require serious expense to carry out; in fact, they are more in the way of conducting a test than otherwise.

"First, I would try to run the machine on a 10-pound to 15-pound (more or less, according to temperature of brine) suction pressure.

"Second, I would put more liquid in the coils of the refrigerator; say to the extent of filling them half full or a little more.

"Third, I would dispense with the drum collecting the liquid from condenser and return the liquid directly to the refrigerator, regulating the return flow by the regulating valves.

"In a general way, it strikes me that for such liquids the apparatus should be as simple as possible. All drums, receptacles, or open spaces in which the two gases may have a chance to separate (if there is no combination, which may be true for all saturation or,

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at least, for a saturation higher than a certain proportion of carbon dioxide or sulphur dioxide) should be avoided.

"The suggested changes do not involve any extra expenses or alterations in the apparatus; with them better results might be secured, and, if at all successful, even suggest a line in which still better ones could be hoped for. Beyond that I would not advise you to go, nor to incur any further important outlay in the present circumstances and for the time being."

In commenting upon the above report of Mr. Rossi it is not admitted that the plant was not suitable for sulphur dioxide when used alone or for a binary compound of sulphur dioxide and carbon dioxide. It is true that sulphur dioxide when used alone gave an amount of refrigeration in this apparatus, when compared with ammonia, only proportional to the pump displacement and the respective heat-carrying capacities of the two gases, but refrigerating engineers recognize the value of large condensing and refrigerating surfaces and the absence of clearance space in the compressor, and as these were especially favorable the binary should have made its best showing. The effect of having a larger quantity of liquid in the condenser in order to give more time for the absorption was tried by increasing the charge as the experiments proceeded, but without apparent results.

If the criticism be made that the speed of the compressor was unfavorable to the binary, this is answered in the final tests, where the revolutions were reduced from 115 to 85 per minute, and where no better results were obtained than in the tests made at the ordinary speed.

The author, for the following reasons, is of the belief that any combination of gases in any arrangements of refrigerating apparatus will not commercially produce a greater efficiency than a single gas:

Assuming even that in the condenser the gases are absorbed or dissolved one into the other, in their passage through the refrigerator they have become laden with heat according to their respective capacities, and it is the function of the condenser to absorb this heat. If the union of binary gases really formed a new compound, then the heat equivalent of work would not be changed because of a change of the physical or chemical properties of the gas used. This is proven by the wide range of pressures of the binary gas when used in practice, varying from as low as the pressure of sulphur dioxide to the high pressure of carbonic acid. If one gas absorbs another it does not dispose of the heat carried either by itself or the other gas,

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which must be taken away by the condensing water, refuting the Delamater claim that less cooling water is required.

If it were possible to lower the working condenser pressure to secure liquefaction with a given temperature of condensing water in a condenser of ample surface by utilizing the function of absorption of one gas for another, thus cutting down the condenser pressure to perform liquefaction, the less resistance to the compressor would mean less power to drive it; but even this is not proven.

Finally, even if it could be demonstrated theoretically that the binary mixture of a proportion of 20 pounds of carbon dioxide to 100 pounds of sulphur dioxide would approximate in refrigerating effect ammonia used alone in an ammonia outfit, the tests showed conclusively that it would not do so, for practical reasons. The tests also showed that any other proportion of the liquids named would not give any better economy than sulphur dioxide or ammonia alone, and that it was impossible to secure in an ammonia refrigerating apparatus by actual trial, using the patented binary, the same amount of refrigerating work as from ammonia.

With the heavier charges of carbon dioxide in sulphur dioxide the behavior of the machine was most irregular. The temperatures and pressures fluctuated greatly, and there were alternate frosting and thawing on the pump and exposed pipe surfaces. At times the pressure ran up to the danger point, 400 pounds and above, so the hand of the gauge brought up against the stop pin. This peculiar action showed that there was no union or co-operation of the gases, the carbon dioxide running through the system separately and distinctly, refusing to affiliate with the sulphur dioxide, or, at least, probably collecting in portions of the condenser until forced out by a surge of gas, or, if mixed at all, to break away as a highly saturated gas. In the evaporative paroxysms the carbonic acid passed through to the expansion valve in flashes, suddenly lowering the temperature to 40° F., and below zero or lower, and actually freezing the crude oil bath in which a spirit thermometer graduated from —70 to +70 was immersed, or, at least, solidifying it so that upon lifting the thermometer the oil clung to the bulb in a mass.

This erratic flow of gases accounted for the spasmodic irregularities in temperature and pressure conditions which we found would not yield to intelligent adjustment and control.

The advisability of substituting a 10-inch bore compressor pump in place of the one of 6½-inch bore was considered in order that comparative tests might be made for capacity between ammonia and sulphur dioxide, and in which the engine revolutions might be

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adjusted to give each gas the proper displacement, the remainder of the apparatus to be used as it was. Owing, however, to the failure of the binary to make a good showing, this was not deemed of sufficient commercial importance to justify the expense, especially as the extended use of ammonia and sulphur dioxide machines had determined largely what constituted good practice in the proportion of all the essential parts to meet competition with its rather low ideals of efficiency and where it is necessary in some instances to avoid high economy, to secure which might add too much to the first cost of the apparatus and necessitate a higher selling price. The tests were solely to determine the capacity and efficiency for a binary compound of sulphur dioxide and carbon dioxide, and those made with sulphur dioxide alone and ammonia alone were merely incidental—that is, they were made only for throwing a sidelight on the main point at issue. All data were, however, taken quite as carefully in one test as in the other.

At times during the experiments the thermometer of the expansion header near but beyond the feed-regulating valve showed abnormally low temperatures which were continued for considerable intervals, leading the writer to hope that a condition of adjustment had been reached from which superior results would be realized, but the thermometers in the header at the other end of the evaporating coils were not affected. These abnormally low temperatures, caused by spurts of low temperature liquid, probably exhausted themselves in the first few feet of evaporating surface with which the liquid and gas came in contact, and immediately thereafter the brine temperatures became warmer, because such conditions temporarily cut off the circulation of the real refrigerating gas, sulphur dioxide.

After starting a test the maximum refrigerating output for the mixtures in use was found by trial, and the machine was run under those conditions of adjustment for a sufficient length of time to be sure that they could be indefinitely maintained; the results for the condition were then considered established and the next test proceeded with.

Digressing from the strict matter of this paper, the writer admits no distinction in the refrigerating efficiency of the several single gases used in practice when the apparatus in which each is used is correctly proportioned to the cold storage or ice-making temperature to which the gas may be suited without regard to size and cost of apparatus, and provided it is so arranged as to overcome mechanical difficulties of construction to withstand any excessive pressures and corresponding leakages. In some cases the apparatus should be spe-

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cially adapted for phenomenally low temperature work through a large increase of heat-absorbing surface and pump displacement. To make the selection of the proper agent and apparatus to secure the best practical results with lowest first cost is exclusively within the province of the refrigerating engineer.

One purpose of this paper, so hastily prepared, is to expose the binary refrigeration theory and call the attention of refrigerating engineers to the ready acceptance by scientific men of theories at variance with the laws of nature, and if authorities, so called, are not particular, then the refrigerating engineer must be the more careful to apply the thermodynamic laws to all heat problems before putting theory into practice, or before, as it were, writing his name in large characters where he makes mistakes involving expensive mechanical construction.

DISCUSSION.

John E. Starr—I was especially glad to hear Mr. Penney's paper, because some years ago I made experiments on almost the same line. Singularly enough, the experiments coincided almost exactly with the theory; but the latter was quite different from that of the authority Mr. Penney has quoted. We used a combination of bisulphide of carbon, instead of sulphur dioxide, with either dry air or carbon dioxide. Exactly equivalent results were obtained with both. The carbon bisulphide was condensed in the usual way in a tubular condenser and air was admitted. Air or carbon dioxide was forced into the top of this condenser until a pressure of about 15 or 18 pounds to the square inch at a temperature of about 70° was obtained. Carbon bisulphide was led in the usual way to an expansion coil.

Just beyond the expansion valve another expansion valve, which was connected with the top of the condenser, was inserted, bringing the mixed carbon bisulphide and the carbon dioxide just beyond the expansion of the liquid and mixing at that point. The results were, as might be expected, that much lower temperatures were obtained than were secured by the use of the carbon bisulphide alone. That is a simple question of the absorption of the gas, the same as in the water tower, where the water is absorbed in the air. If any non-condensable gas is blown over the liquid it will absorb the liquid and lower the temperature rapidly.

The calculation on this machine that I made at the time—I had no knowledge of these other experiments—was this, that while the lower temperature would be obtained the liquefiable gas was the

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only gas that did any refrigeration, and by assigning the proper latent heat to the liquefiable gas, that is, the carbon bisulphide, and figuring it out point by point, we would only take up as much heat as was due to the saturated gas after the usual allowances were made.

The effect of the non-condensable gas, the carbon dioxide, was simply that of lowering the temperature by absorption, and that dead gas, as it might be termed, had to be carried through the compressor, putting additional bulk in the compressor; then when it was compressed in the condenser the liquefiable gas would fall out and leave above it a mixture of the non-liquefiable gas and the liquefiable gas, in proportion to their vapor tension.

At that time I made a calculation of the state of the two gases in the refrigerator and in the condenser, and figured what the volume would be in the compressor and the number of pounds of carbon bisulphide that would be cooled, and I obtained certain results, which showed that the horse power in the compressor would be greater than enough to offset the additional low temperature obtained, and that the horse power per ton would be greater.

In running the tests, which were made over a period of three or four weeks, the results came as close to theory as results of experiments of that kind usually do, that is, within 5 or 6 per cent. They are practically the same as Mr. Penney has given us in his paper, and they thoroughly satisfy the theory of figuring the state of the gases in the condenser and in the expansion coil on the basis of the well-known law of the absorption of a gas in a gas, and the resulting volume at given temperatures.

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No. 23.

DESCRIPTION OF A COLD STORAGE PLANT UTILIZING EXHAUST STEAM.

By Henry Torrance, Jr., New York, N. Y.

(Member of the Society.)

The purpose of this paper is to show what can be done in cold storage warehouses with the absorption system of mechanical refrigeration in practical operation, using exhaust steam from the auxiliary machinery.

The plant described is that of the L. C. Bates Company, New Haven, Conn.

The original cold storage plant was built in 1892. The No. 1 warehouse, still in use, contains about 140,000 cubic feet of space, measured inside the insulation, including the ante-rooms. The insulation was built of boards, paper and sawdust, in all about 10 inches thick. About one-third of the house is made up of freezing rooms and the remainder contains rooms held at 30° to 40°.

A 15-ton absorption machine was installed, with horizontal tubular boiler, duplex water pump, duplex brine pump and duplex boiler feed pump, single cylinder ammonia pump and a 15-horse power vertical engine for running the elevator and dynamo.

During the thirteen years of operation since its completion, from 1892 to 1904, inclusive, the brine was generally held at 5° and the freezers at 15°. In summer the coal consumption was about 1.8 tons per day, all exhaust steam going to waste.

In the winter of 1904 the entire old refrigerating plant was taken out, a new plant, consisting of two 25-ton machines, as described hereafter, was installed in a new building, and this machinery was used in 1905 to cool the old building. The coal consumption during June, July and August, 1905, was 25 gross tons per month, or an average of .83 gross ton per day. The brine was carried at about 15° below zero and the rooms maintained from zero degree upward. Thus a little more work was done with the new plant in 1905 than with the old plant in 1904, and with a little less than half the coal, showing a saving of over 50 per cent.

In the winter of 1905 the new warehouse was completed and added to the system. It has eight floors 10 feet high, six and one-half floors being insulated with 4 inches of Nonpareil sheet cork

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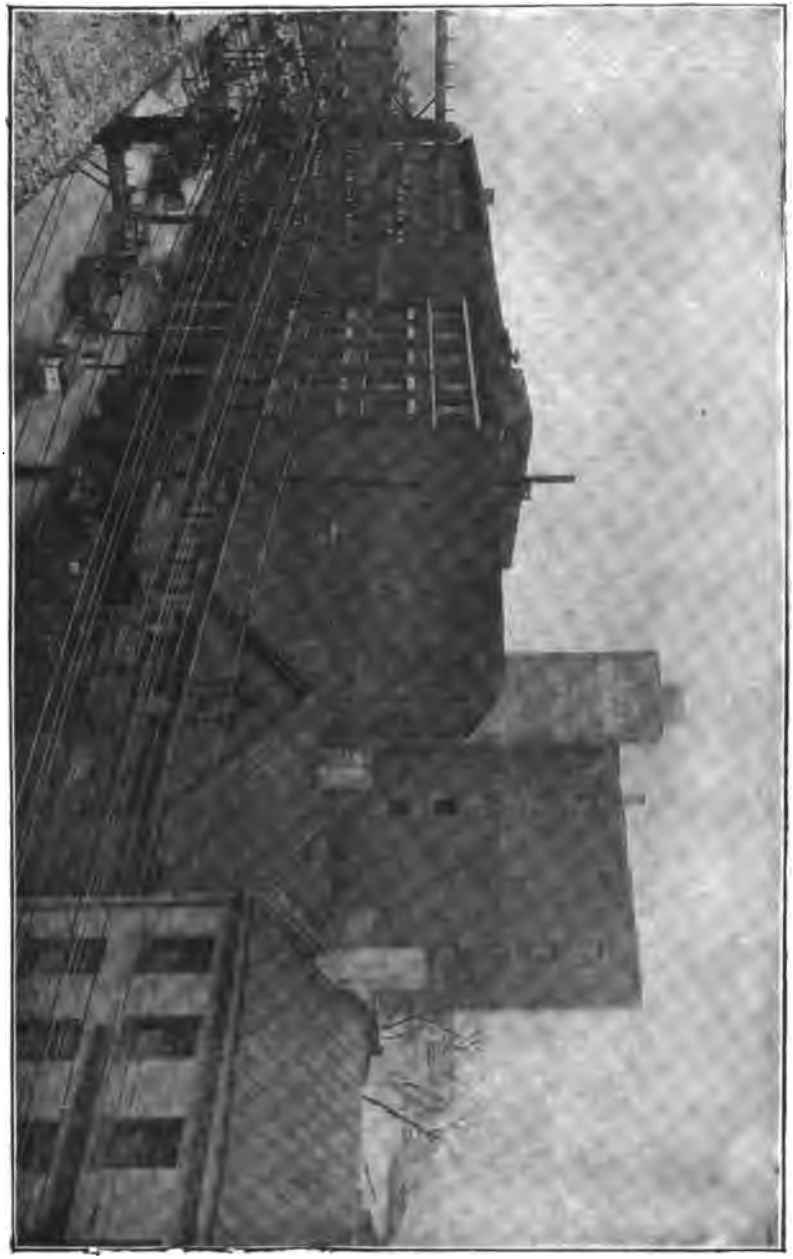

EXTERIOR VIEW OF THE COLD STORAGE PLANT OF THE L. C. BATES COMPANY.

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finished with cement, and each containing 3,100 square feet of floor area, measured inside the insulation, making a total of 201,000 cubic feet. One room was shut off, so that the total space cooled was as follows:

Year.	Machinery Used.	Space Cooled (About One-third Freezer). Cubic Feet.	Tons Coal Per Day.
1892 to 1904	Old 15-ton plant.	House A, 140,000	1.8
1905	New 50-ton plant, two units.	House A, 140,000	.83
1906	New 50-ton plant, two units.	House A, 140,000 House B, 190,000	1.3
		Total.... 330,000	

TEMPERATURES MAINTAINED.

The following is a list of the rooms, with the temperatures maintained on July 3, 1906, showing average conditions:

Warehouse A.		Warehouse B.	
Room.	Degrees.	Room.	Degrees.
21	37	81	35
34	37	82	32
23	36	31	30
41	36	51	30
43	34	61	30
51	34	71	30
35	30	32	4
42	30	41	0
44	30	42	—8
52	29	..	..
32	23	..	..
22	17	..	..
33	6	..	..

COAL CONSUMPTION.

The coal used during the summer of 1906 was as follows:

	Gross Tons.
Coal in bin May 1	1.0
" bought in May	51.0
" " June	52.0
" " July	48.3
" " August	28.9
" " September	23.2
Total	204.4
Coal in bin September 30	1.0
Total coal used	203.4
Total number of days from May 1 to September 30	153
Average coal used per day, gross tons	1.33

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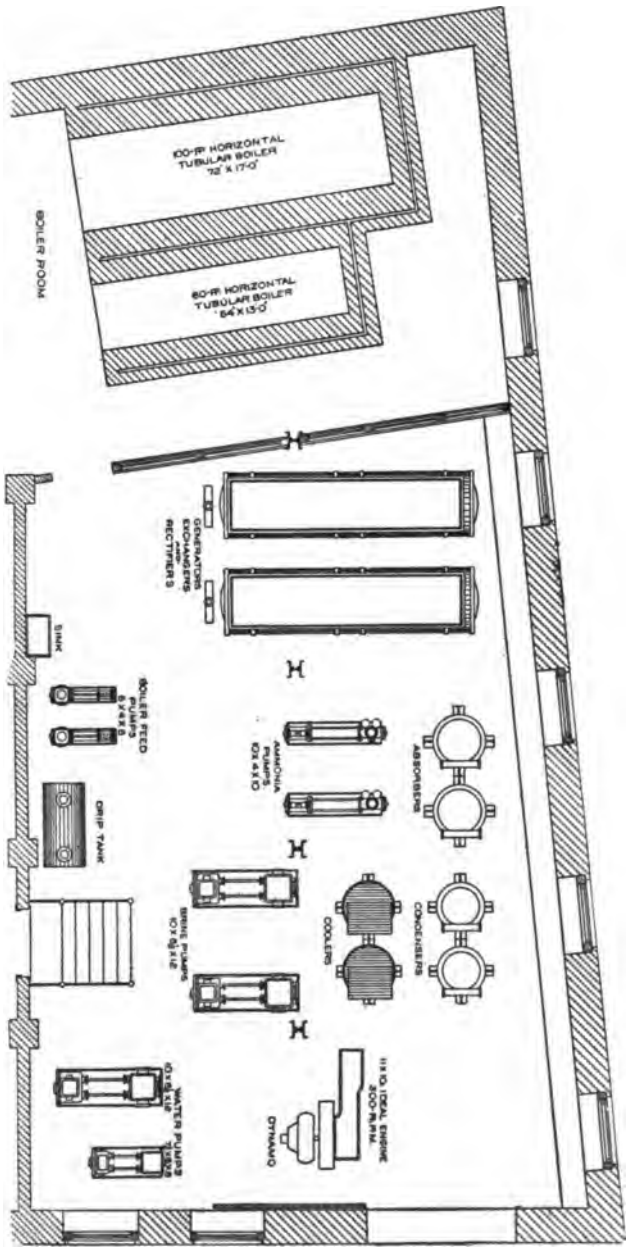

FLOOR PLAN OF THE COLD STORAGE PLANT OF THE L. C. BATES COMPANY.

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This coal was sold by the dealer in New Haven as "Cumberland soft coal." It was not weighed, but the above quantities were the amounts paid for, and it would be a slur on the coal dealer's intelligence to say he gave overweight.

MACHINERY.

The refrigerating plant consists of the following parts:

One horizontal tubular boiler, 72 inches by 17 feet, set in brickwork.

One horizontal tubular boiler, 54 inches by 13 feet.

One iron flue connecting both boilers to stack.

Two 25-ton special absorption refrigerating machines of the closed type.

Two direct-acting steam ammonia pumps, each 10x4x10 inches.

Two duplex brine pumps, each 10x8½x12 inches.

One duplex water pump, 7½x6x8 inches.

One duplex water pump, 10x8½x12 inches.

Two single cylinder boiler feed pumps, each 6x4x8 inches.

One 50-horse power Harrisburg automatic engine, 11x10 inches, with direct connected dynamo running 300 r. p. m.

Two elevators.

One 5-horse power electric motor for fur-room fan.

One Utility feed-water heater and purifier.

One damper regulator.

Two Anderson steam traps for generator drips.

METHOD OF OPERATION.

The boiler pressure was generally kept at 90 pounds, and a 4-inch steam pipe conveyed steam to each of the four pumps and engine. The exhausts of all these pumps and engine were joined together and run into the oil-separating compartment of the Utility tank, generally under a pressure of about 5 pounds, and the boiler feed pump delivered it to the boiler hot, generally at a temperature of 220°. To supply the leakage of steam and waste from the oil separator, drips, stuffing boxes, etc., enough fresh water was fed daily into the boiler to raise the level about 12 inches, as shown by the gauge glasses, which seemed to be sufficient to maintain the proper level. This water was fed in slowly during the daytime, but none whatever during the night. For this reason the boiler remained free and clear from scale.

The duplex water pump sucked water direct from the wells at a temperature of about 50° and delivered it to the refrigerating

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View of the Engine Room of the Cold Storage Plant of the L. C. Bates Company.

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machines, the waste water running to the sewer. City water was used in the boilers, and, as mentioned above, the quantity was nominal; as a matter of fact the city water bill with the new house was very much lower than the water bills were formerly with the old plant.

LABOR.

A chief engineer, who also took the temperatures in the cold storage rooms, ran the plant, having one fireman on days and one fireman on nights, making three men in all. The writer is indebted to the chief engineer, Mr. John Nash, for the data mentioned above, and wishes to say furthermore that the results obtained are largely due to his excellent management.

DISCUSSION.

Gardner T. Voorhees—What was the pressure of the steam as it went to the ammonia generators and what was the temperature of the condensing water used?

Henry Torrance, Jr.—The temperature of the condensing water was 56°; the pressure of steam varied, but it was generally about 5 pounds. It would vary, as you would see from the logs, which I have not brought, from 3 to 9, but the average was 5.

F. W. Pilsbry—What is the tonnage of the refrigerating plant?

Henry Torrance, Jr.—I cannot say what the tonnage is, and I do not know—this is supposed to be a practical paper. You will have to guess at the tonnage from looking at the buildings and taking the figures of the cold storage spaces.

Gardner T. Voorhees—Were both of the generators in operation?

Henry Torrance, Jr.—They were both in operation during the greater part of the summer. One was out of business for a couple of days once, and during that time one machine barely held the load at a higher capacity. My impression is that the average tonnage would run around 35 to 40. I should say around 40 in the hot weather, but I cannot tell.

Carl W. Vollmann—How much steam was used per ton of refrigeration?

Henry Torrance, Jr.—To answer that question I would have to go into the theory, because there are no data here to show how many tons were used during the summer to cool those houses.

Carl W. Vollmann—As we all know, although you give the exact figures as regards coal consumption, this depends in a great measure

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upon the boilers. Can you not state what amount of steam was used?

Henry Torrance, Jr.—My belief is that the boiler, which was a horizontal tubular one, was very good. It was perfectly clean. It had a light load and a damper regulator. It was handled carefully. I believe the fireman handled his coal carefully, and that a part of the economy of the plant was due to the good condition of this part of the plant.

Carl W. Vollmann—Your paper is very good, and the results are good, but I think it would have been of greater value to us if the steam consumption had been given, besides the consumption of coal, the pounds of steam used per ton of refrigeration, the temperature of the brine, the steam pressure, etc., so that we could study the figures given us.

Henry Torrance, Jr.—I can only give my opinion, which may not have any particular value. It is probable that the machine in this plant consumed in the neighborhood of 27 pounds of steam per hour per ton of refrigerating effect. The exhaust steam was, of course, all taken from the auxiliaries, and there was practically no live steam. Does that answer your question?

Carl W. Vollmann—To a certain extent, but I notice that you have not the figures, and consequently you cannot give them to us.

Gardner T. Voorhees—What was the back pressure and were two back pressures used?

Henry Torrance, Jr.—In looking over the logs I notice that the brine ran from 10° to 5° below zero during the summer. I did not notice the back pressures, but they were pretty low, probably 5 pounds on the coolers.

Gardner T. Voorhees—Five pounds gauge on the coolers?

Henry Torrance, Jr.—Yes.

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No. 24.

REFRIGERATION OF BUTTER AND CHEESE.

By C. E. Gray, United States Department of Agriculture.
(Non-Member of the Society.)

The subject of refrigeration of butter and cheese suggests only at first thought the holding of these products at low temperatures, as in transportation or cold storage. However, I do not wish to limit the subject to this alone. While refrigeration (and I refer especially to refrigeration produced by artificial means) is an important factor in the storing of butter and cheese, it has a place in the manufacture of butter and in the ripening of cheese which must not be overlooked. I hope the time is not far distant when refrigeration may be generally used in the preserving of the raw materials, the milk and cream from which butter and cheese are made. There is certainly great need of better methods for preserving the raw material, thereby improving the quality of the final products. Holding the milk and cream at low temperatures seems to be the most feasible means of accomplishing the desired results. I shall refer to the possibilities of milk and cream refrigeration later.

In the manufacture of butter it has been proven beyond a doubt that, in order to make a uniform product, definite methods must be followed. This means definite temperatures for ripening cream, for cooling cream for churning, and definite temperatures for washing the butter, all of which are lower than the summer atmosphere and necessitate the use of natural ice or artificial refrigeration. In the United States there are today about 8,000 creameries, only a small percentage of which are equipped with refrigerating apparatus. All others are dependent on natural ice for cooling. This, where the supply is sufficient each year, is quite satisfactory, but in no case as satisfactory or convenient as refrigeration produced by artificial means. For these reasons and because the supply of natural ice is not always sufficient, especially as we go farther south, many creameries are each year installing refrigerating apparatus. There is quite an opening along this line for the manufacturer of small plants of 10 tons' capacity or less, machines which are simple in construction and easy to operate.

Of all food products held in storage butter is at least second in

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importance. Unfortunately the uncertainties of butter storage are perhaps greater than those of the storage of other products. If butter when placed in storage would remain unchanged during a period from six to nine months we would consider the results very near ideal, and when such results are obtained the stored article will have advantages over fresh butter for this reason. During summer months (the season of storing) the quality of butter is generally recognized as being materially better than of that made during the winter months (the season of removing from storage). I feel perfectly safe in stating that there is butter in storage today, placed there last June, which is now as good as, if not better than, what is being made at the present date. Stored in the same room with this is other butter, which seemed equally good at the time of storing, but which now has characteristic cold storage flavors. This is an occurrence of too great frequency. Why this deterioration in some and not in all of the butter is a problem yet to be solved. One thing which seems to be very certain is that the development of undesirable flavors cannot be wholly prevented by holding the butter at low temperatures, at least at such low temperatures as would be practical for general storage. If we read articles on the storage of butter published only a few years ago we find 20° F. given as suitable temperature, and the lowest temperatures suggested are about 5° above zero. Storers of butter have each year been demanding lower temperatures, until now we find very few butter rooms held above zero, many lower, and a few as much as 10° F. below zero. I presume that if it were practical still lower temperatures would be used, as ideal results have not yet been obtained. I believe that you refrigerating engineers have done toward producing storage which will give satisfactory results all that you should be asked to do, perhaps more. You are holding butter rooms at temperatures lower than are used for storing other food products. It seems wholly reasonable that the manufacturer of butter should be asked to take a part, and if necessary make a butter especially for storing. It is along this line that the Dairy Division of the United States Department of Agriculture is working. We are this year studying keeping qualities of butter as affected by "ripening" (i. e., the sourness of the cream at the time of churning). We have in storage butter from cream having varying amounts of acidity, ranging from perfectly sweet to what is termed "over-ripe." We are also giving attention to the effects of pasteurization. While we have not been able to make a butter perfectly sterile, we have made some which was more nearly free from organized and unorganized ferments than

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ordinary butter. Most of the butter was carefully analyzed, both chemically and bacteriologically, at the time of placing in store, and will be again analyzed when removed. The first lot will be taken from storage the 15th of this month. This investigation will undoubtedly give some very interesting and, we hope, valuable results. The work of 1905 has been published in Bulletin No. 84 of the Bureau of Animal Industry. Doubtless many of you have read this publication, but I wish to refer to it briefly. The object of the investigation reported in this bulletin is to study the keeping qualities of butter:

1. As affected by temperature of storing.
2. As affected by pasteurization of cream.
3. As affected by salting.
4. As affected by package in which it is stored, as (*a*) tubs, and (*b*) cans, so-called hermetically sealed.
5. As affected by air in the package, as in (*a*) cans full and (*b*) cans partially full.

The results which I consider worthy of mention are, first, that there was not a great difference between the keeping qualities of butter stored at —10° F. and at +10 F., the average difference of all scores being .51 point in favor of —10°. Between —10 and +32 there was a marked difference in favor of the lower temperature. Another point of interest is that butter in so-called hermetically sealed cans kept no better than butter in tubs. When the cans were not filled completely full the deterioration was much greater than when the cans were filled. This deterioration was undoubtedly due to the butter coming in contact with air in the package. I think it has been generally recognized that butter must not be exposed to air while it is in storage, and that it is advantageous to have butter packed solid and in large packages. Butter having higher percentages of salt did not keep as well as that with lower salting. In studying the keeping qualities of this butter after removing it from storage the following, which seems of great importance, was noted—that butter made from cream of good quality was far superior ten days after removing from storage to the butter made from cream of inferior quality. With our present knowledge of the storing of butter it seems necessary to store good butter in order to have it at all desirable any length of time after removing from store. It seems that this fact may not hold true when storing cheese. It is the opinion of Mr. Doane, expert in charge of cheese investigations for the Dairy Division, that very often cheese which seems poor enough at the time of storing to warrant a cut in price comes out of storage

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a few months later of such quality as to bring the highest market price. The Dairy Division is conducting investigations along this line, attempting to determine definitely whether or not poor cheese does become of better quality when ripened at low temperatures. Other work is being done with the object of determining what temperatures give the most desirable results, and how soon after making the cheese should be placed under refrigeration. Results thus far obtained indicate that it is desirable to place the cheese as soon as possible after making in cold rooms. Temperatures below 35° F. have given very satisfactory results. It seems that the most satisfactory method for ripening cheese will necessitate artificial refrigeration, also that it will be desirable to have the refrigerated curing rooms as near as possible to the cheese factories, in order that the cheese soon after making may be placed in them. If these facts are established there will be an additional demand for refrigerating apparatus.

I wish to refer now to the refrigeration of milk and cream. To manufacture good butter, and we must have good butter if we wish to store it, we must have good cream, and to manufacture good cheese a milk of good quality is essential. The tendency is for producers of milk and cream to make less frequent deliveries to the cheese factory and creamery than formerly. This is especially true regarding producers of cream since the introduction of the hand cream separator. There could be no objection to this less frequent delivery if the quality of the product was good. However, it has not been. The average quality of the butter of the United States has the last few years been becoming poorer, rather than better, owing to the increased use of the hand separator and less frequent delivery of the cream. What is now needed is a satisfactory method of holding the milk and cream in good condition up to the time of delivery. The length of time which milk and cream can be held in good condition is determined by two things—the cleanliness with which it is handled and the temperature at which it is held. We would not like to admit that refrigeration is more essential than cleanliness, but we know this to be true. Even by using the greatest precaution in milking and handling milk and cream it is practically impossible to obtain them absolutely free from bacteria. When we think of the rapidity with which bacteria multiply, conditions being favorable, a single bacterium reproducing itself in from fifteen to forty minutes, we realize that milk held at ordinary temperatures in the course of twenty-four hours will contain many million per cubic centimetre.

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One of the easiest methods of arresting the development of bacteria is by subjecting them to cold. What the producer needs is refrigeration. Nothing could do more toward the producing of good butter and good cheese than the holding of the cream and milk at low temperatures, from the time of milking up to the time of delivery at the creamery or cheese factory. Knowing this, the Dairy Division of the United States Department of Agriculture, also the dairy sections of the various experiment stations and colleges, are doing what they can to induce the farmers and dairymen to use water and natural ice for cooling. The Dairy Division has been sending out plans for building ice houses, and giving all the information it can regarding the benefits to be derived from the use of ice. In some sections of the country, where the possibilities for producing milk are greatest, natural ice is nearly unknown. The producer in these sections is almost wholly dependent upon artificial refrigeration, and at the present time has very little.

Let us review briefly the relations of refrigeration to butter and cheese.

To obtain the best finished products we ought to have it for preserving the raw materials (milk and cream). To obtain a uniform grade of butter we are dependent upon definite temperature during this process of manufacture. We must have cold storage to keep butter from the period of greatest production until times of shortage. The value of cold curing of cheese is each year being better understood. The manifold relations between refrigeration and dairy products make us aware of what we owe the refrigerating engineers. I wish to assure you, in behalf of the dairy interests of the country, that your work is appreciated; but we wish to impress you, both collectively and individually, with one possibility, as yet undeveloped, that of a refrigerating apparatus, simple enough, cheap enough and efficient enough to be of practical value to every dairy farmer.

DISCUSSION.

S. P. Stevenson—I would ask Mr. Gray whether the temperature of cold storage rooms for cheese should be held lower than 32°. I think he said that cheese should be stored between 35° and freezing. Did he mean the temperature at which cheese would freeze or did he mean 32°?

C. E. Gray—Very little has been done, so far as I know, in holding cheese lower than 32°. In my paper I meant between 35° and 32°. I think it has not been found desirable to use temperatures lower than 32°, but very near that point.

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John E. Starr—Will Mr. Gray tell us whether the low temperature limit for long storage butter has been reached? He states, and as many of us know, that butter is now being stored at as low as 10° below zero. I think it would be very interesting to know how much further we have to go, if at all.

C. E. Gray—That is something that will have to be taken up, providing a different method for manufacturing butter does not remedy the difficulty. Nothing has been done so far as I know in holding butter lower than 10° below zero, and we find from the results obtained that there is very little difference between 10° above zero and 10° below. We might assume from that that a lower temperature would not be of much greater value, and then when we employ a lower temperature than 10° below zero we will find the proposition quite an expensive one; at least I have been led to believe so. What we hope to be able to accomplish is to manufacture butter which will keep at temperatures a little above zero, perhaps as much as 10° above.

John E. Starr—There is a marked difference between 10° above and 10° below.

C. E. Gray—No; there is not a marked difference, but as we go above 10° above zero we also find a marked difference in the keeping of butter.

Carl W. Vollmann—Has Mr. Gray ascertained in any way the effect of impurities in the air in the storage rooms on the goods stored therein? Perhaps I should mention before asking for an answer that when refrigeration was first introduced—I am talking now of some years back, when the export of frozen goods from the British colonies, New Zealand and Australia, began and these goods were stored in London—we found, although the temperature was kept low, we could not prevent mould growing on the carcasses. We tried to overcome the formation of the mould by lowering the temperatures, and although we retarded its growth we could not prevent its formation. Upon investigating the matter more thoroughly, we found that it was mostly due to the impurities in the air. To a certain extent all stored goods, that is all perishable goods, breathe, as we expressed it, after they are stored; that is to say, they absorb a certain amount of air and give off, instead, impurities which settle on the goods stored. We found that if we could keep these impurities out of the air by removing or destroying them we could obtain better results with higher temperatures than with lower. Why I mention this matter is that if the Agricultural Department has not investigated along this line it would be

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perhaps well for it to do so, as it has facilities and can make investigations wherever it likes. It should make such investigations to find out whether by keeping the air absolutely pure, or as far as possibly so, better results cannot be attained and retain the natural flavor of the goods.

C. E. Gray—In reply to the gentleman's remark I may say that we have attempted to keep the air in the storage rooms as pure as possible. We know that where butter is exposed to air which has bad odors they will be absorbed. Butter in hermetically sealed cans really kept no better than butter in tubs, which would indicate that pure air would not solve the problem.

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No. 25.

MULTIPLE EFFECT COMPRESSORS.

By Gardner T. Voorhees, Boston, Mass.

(Member of the Society.)

At given temperatures the weights of a given volume of gas are proportional to their absolute pressures. The refrigerating capacity of a compressor is proportional to the absolute suction pressure of the gas pumped. Low temperatures can only be produced at low suction pressures, and so require larger compressors to produce a given amount of refrigeration than do higher temperatures, with their consequent higher suction pressures.

In analyzing the action of the compressor by the use of diagram 1, A A is the atmospheric line; V V is the vacuum line; Vb_1 the absolute suction pressure in the compressor cylinder at the end of the suction stroke, a_1 b_1 is the suction line, b_1 c_1 the compression curve, c_1 d_1 the discharge line, d_1 a_1 the drop in pressure from the end of discharge to the beginning of the next suction stroke.

If the temperature of the gas at discharge is constant, then for a given discharge pressure the length of line c_1 d_1 is proportional to the weight of gas pumped, and therefore a measure of the refrigeration done by the compressor. If line c_1 d_1 were twice as long the compressor would be doing twice as much refrigeration, and if the line c_1 d_1 were half as long the compressor would be doing half as much refrigeration. With the suction gas at constant temperature, if the absolute* suction pressure Vb_1 were twice as much, the compressor would be doing twice as much refrigeration, and if half as much then the compressor would be doing half as much refrigeration.

Let indicator diagram 2 be taken from a compressor of half the displacement and at the same discharge pressure as that of diagram 1. Here the suction pressure Vb_2 and the discharge line c_2 d_2 are twice as long as the suction pressure Vb_1 and the discharge line c_1 d_1 of indicator diagram 1; so that this compressor, of one-half the displacement of that of diagram 1, pumps gas twice as dense and so does just as much refrigeration as the compressor of twice the displacement.

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* Note.—Absolute pressure is the gauge pressure plus the pressure of the atmosphere, usually taken as approximately 15 pounds per square inch.

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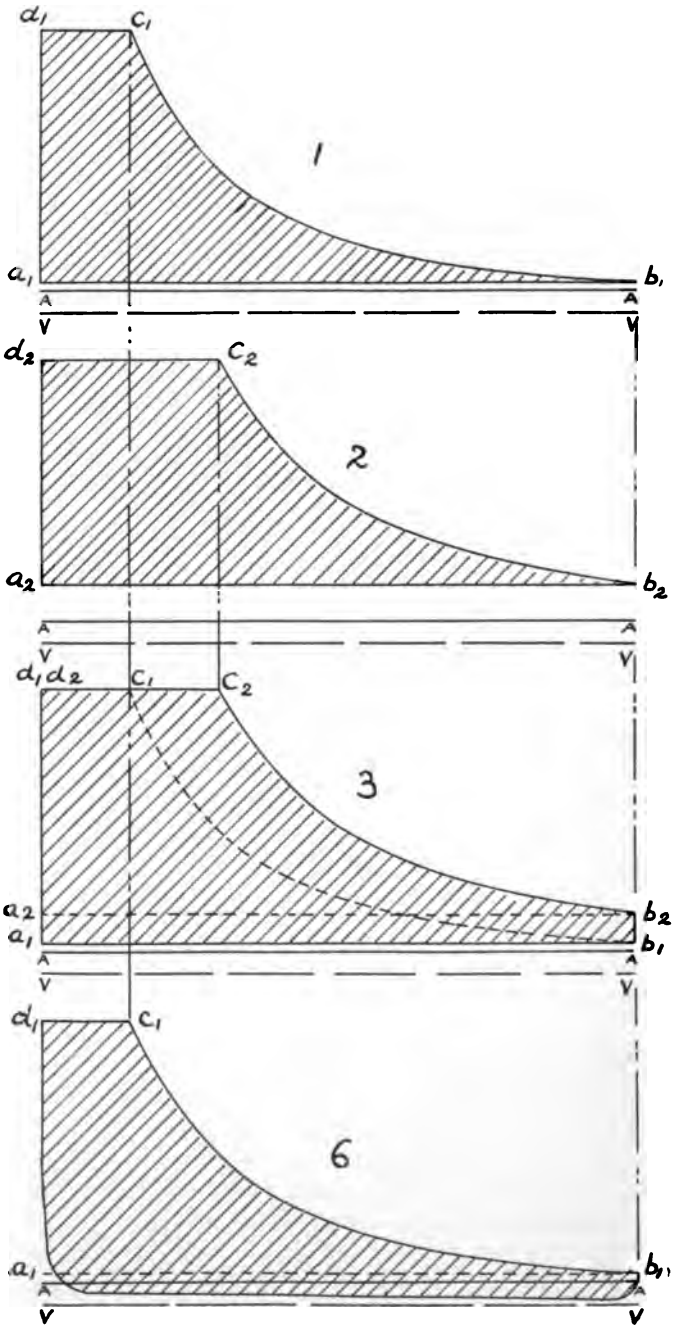

DIAGRAMS, FIGS. 1, 2, 3 AND 6.

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Place diagram 2 on diagram 1, as shown in indicator diagram 3, so that vacuum lines V V and discharge points d_1 and d_2 coincide. As the suction pressure Vb_2 is greater than the suction pressure Vb_1, it will be evident that, if a compressor is properly designed, gas at the higher suction pressure will flow into the cylinder that is already full of low pressure gas, until the lower pressure gas has made room for and been compressed by the high suction pressure gas to its high pressure. A cylinder so designed and operated I have called a "multiple effect compressor" (hereafter referred to as M. E. C.). Its theoretical indicator diagram is the outside bounding line of diagram 3 and its action is: suction of low pressure gas on line a_1 b_1, inflow of high suction pressure gas at b_1 and compression of low pressure gas thereby to b_2, without the aid of energy from the steam engine; compression of the gas from b_1 to c_2 and its discharge to d_1 d_2 and drop of pressure to the beginning of the next suction stroke a_1. The M. E. C. diagram 3 shows that at the same speed and with the same displacement as the compressor that made diagram 1, the M. E. C. did all the refrigeration done by the diagram 1 compressor plus that which was done by the diagram 2 compressor, so that it produced 100 per cent. more refrigeration than did the compressor of like displacement operated at the same speed and at the same low back pressure.

Fig. 4 is a simple diagrammatic view of a compression ice-making system with certain modifications. A is the compressor, B its cylinder, C its piston, D its piston rod, which is reciprocated by any desired power; G is the condenser (here cooled with 75° F. condensing water), H the expansion coil, J the forecooler.

In this refrigerating system liquid ammonia at 175 pounds pressure flows through pipe 10, 11, through expansion valve 31 to the expansion coil or cooler, H. In passing the expansion valve the pressure and temperature of the ammonia are reduced and the liquid ammonia is evaporated in coils, H, into gaseous ammonia by the heat from the substance being cooled.

In can ice making the back pressure is usually 18 pounds, the ammonia evaporates at 3° F. and cools the brine surrounding the ice cans to 15° F. The ammonia gas so formed in the expansion coil flows through pipe 13, 14, to the suction inlet of the compressor and during the suction stroke of the piston the gas flows past the suction valve, E, and fills the cylinder, B. During the compression stroke this cylinder full of gas at 18 pounds is compressed to 175 pounds and discharged past the discharge valve, F, and through pipe 8, 9, to the condenser, G, where it is condensed.

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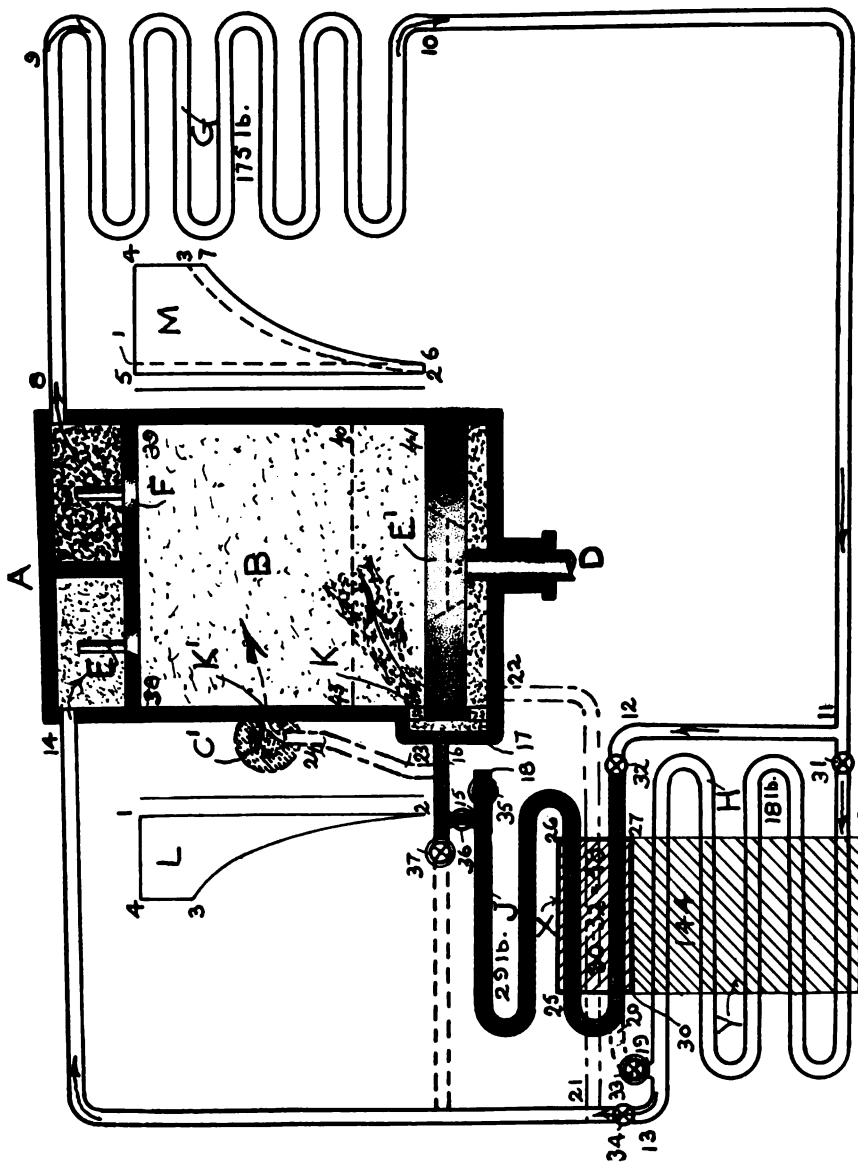

FIG. 4—DIAGRAM OF MULTIPLE EFFECT COMPRESSOR WITH INDICATOR CARDS L AND M.

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Indicator card L (see Fig. 4) shows the variations of pressure in the cylinder during the suction and compression strokes, 1, 2, being the 18-pound suction line; 2, 3, the compression line; 3, 4, the discharge line at 175 pounds, and 4, 1, the drop in pressure between the end of discharge and the beginning of suction.

The water from which the ice is to be made must be cooled from, say, 80° F. to 32° F. before it can be frozen into ice. This water is cooled by the forecooler, J, by the evaporation of ammonia; either by direct expansion through valve 32, when valve 33 is shut and 34 open, or by passing the cold gas and sufficient liquid ammonia from expansion coil, H, through the forecooler coil, J, as through pipe, 19, 20, when valves 32 and 34 are shut and valve 33 is open.

The refrigerating power of the cold gas from expansion coil II is slight and is about balanced by the loss in capacity of the compressor, due to its superheating, so that in either case the water is cooled by the evaporation of liquid ammonia at 18 pounds pressure. The gas so generated must be handled by the compressor. The refrigeration required to cool and freeze the water to ice is represented by area 25, 26, 28, 29; area 25, 26, 27, 30 represents the refrigeration required to cool the water [$(80°—32°) = 48° \times 1 =$ 48 B. T. U.], and the area 27, 28, 29, 30 represents the refrigeration required to freeze the water into ice = 144 B. T. U. It is plain that the refrigeration required to cool the water (area 25, 26, 27, 30) is one-third as much as is required to freeze the water (area 27, 28, 29, 30) into ice ($\frac{48}{144} = \frac{1}{3}$).

With valves 31, 32, 34, 35 and 37 open and valves 33 and 36 shut, the ammonia gas from the forecooler could be taken through pipe 18 to another compressor, in which case the whole refrigerating capacity of compressor A could be devoted to freezing the water to ice in place of first cooling the water and then freezing it.

With two compressors, the first compressor could freeze one-third more ice than it did before, and the second compressor would operate more economically at a higher back pressure than the first one, as it has only to cool water to 32°, while the first compressor has to cool brine to 15°.

The M. E. C. shown in the drawing is single acting, of the Hercules type. To do one and one-third times as much refrigeration as we did before we must compress one and one-third times as much weight of gas as we did before, which is accomplished by first filling the cylinder full of 18-pound ammonia gas and then opening a port into the cylinder so as to allow a body of ammonia gas at a

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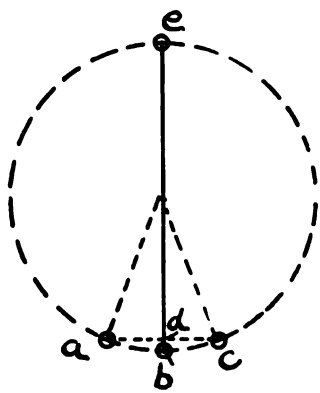

FIG. 5.

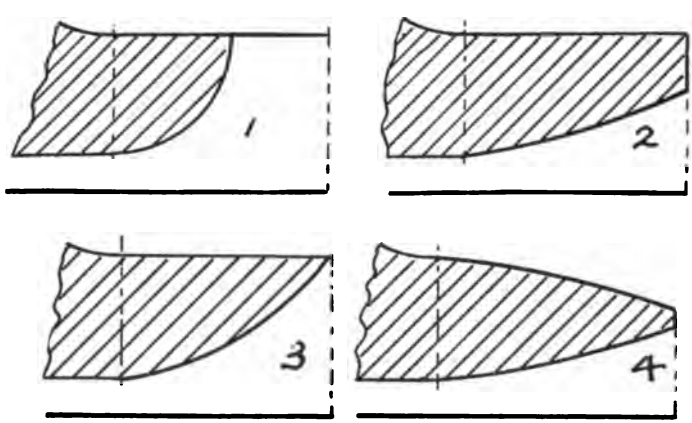

FIG. 7.

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higher pressure to rush into the cylinder and compress the 18-pound gas to such a pressure as to make room for the body of high pressure gas. In this case one-third more weight of gas is to be handled, so the pressure of the higher pressure gas is 29 pounds ($18 + 15 = 33$, $33 \times 1\frac{1}{3} = 44$, $44 - 15 = 29$).

The operation of the multiple effect compressor is, first, as before described, the 175-pound liquid ammonia flows from the condenser, G, evaporates at 18 pounds in expansion coil, H, and fills the compressor cylinder, B, during the suction stroke of the piston with gas at 18 pounds pressure. But in addition to this, liquid ammonia flows from the condenser, G, through pipe, 10, 11, 12, to forecooler, J, where it passes expansion valve, 32, and evaporates in forecooler, J, at 29 pounds pressure while cooling the water from 80° to 32°, all valves being open except 33, 35 and 37.

When the piston reaches the end of its suction stroke and the cylinder B is full of 18-pound gas, the piston C uncovers the port, K, whereat 29-pound gas from the forecooler, J, rushes into the cylinder, B, and compresses the 18-pound gas to 29 pounds, so that the original cylinder full of gas now occupies the volume, 38, 39, 40, 43, while the additional one-third weight of gas rushes in and occupies the volume, 40, 41, 42, 43. Now the piston starts to compress, covers the port, K, and compresses the cylinder full of 29-pound gas to 175 pounds and discharges it into the condenser, G, as before. The variations of pressure in the cylinder are shown by indicator card, M, 5, 2, being the 18-pound suction line; 2, 6, the rise in pressure from 18 to 29 pounds; 6, 7, the compression line: 7, 4, the discharge line at 175 pounds, and 4, 5, the drop from the end of compression to the beginning of suction; lines, 5, 2, 3, 4, representing indicator cards, L, placed on card, M. (See Fig. 4.)

Card 1, 6, 7, 4, would be made by a non-M. E. C. operating at 29 pounds suction pressure, and the power required to operate the M. E. C. would be as follows:

M. E. P. card, L = 70.5, M. E. P. card, 1, 6, 7, 4 = 76.5; 29 — 18 = 11, 76.5 + 11 = 87.5 = M. E. P. card, M. Call friction 25 per cent. of compressor power, then friction = 70.5 × .25 = 18. 70.5 + 18 = 88.5. M. E. P. card, M = 87.5, so 87.5 + 18 = 105.5. $\frac{88.5}{1} = 88.5$. $\frac{105.5}{1.33} = 79$. $\frac{79}{88.5} = 89+$. 100 — 89 + = 10 +, ∴ 10 + % less power per unit of refrigeration with multiple effect compressor under can ice conditions is required than with old type compressor.

I hope it is clear that the M. E. C. is not the same as a double-

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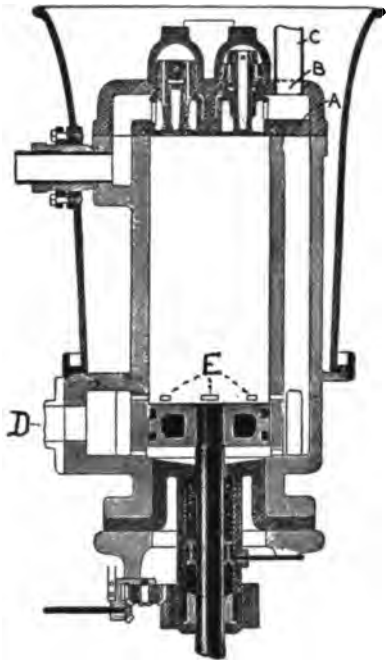

FIG. 8.

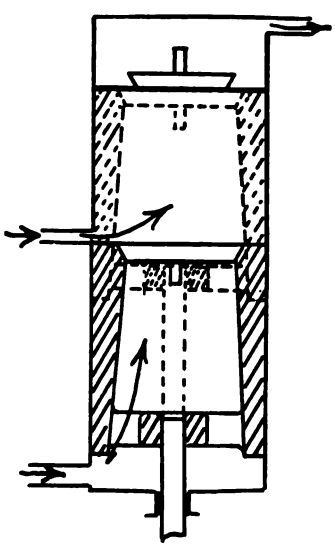

FIG. 9.

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acting compressor which operates with a high back pressure of one side of the piston and a low back pressure on the other side of the piston, for such a combination is the same in effect as two single-acting compressors operated at different back pressures.

In Fig. 5, near the end of the suction stroke, *d*, the piston moves slowly, then stops at *b*, then again moves slowly in the other direction to *d*, during which time the crank pin travels on the arc of a circle, *a c*, so that the relative length of part stroke, *b d*, at this period is very short as compared with the full length of a stroke, *b e*, but the time occupied in making the very small part of the stroke, *b d*, is quite considerable, as shown by the relative lengths of arcs, *a c* and *c e*.

Gas at a fraction of a pound drop in pressure flows with high velocity. I took a number of indicator cards from a Hercules M. E. C. where I had clamped the suction valve shut, with the result that the cylinder took gas only through the little ports at the end of the suction stroke and yet had ample time to completely fill with gas. The indicator card was like that shown in Fig. 6, and although the gas only entered through the little ports E, Fig. 8, at the end of the stroke, yet the length of the discharge line c_1 d_1, Fig. 6, was practically the same as was c_1 d_1 of card (Fig. 1) taken at the same back pressure with the suction valve not clamped.

One of the most interesting studies of the hundreds of M. E. C. indicator cards that I have taken is that of the toe of the diagram under similar conditions, except at different speeds of the compressor. See Fig. 7, where at low speeds the high back pressure gas gets into the cylinder before the end of the suction stroke is reached (1). At faster speeds the high back pressure gas gets completely in during the period that the piston rests at the end of the suction stroke (2). At still faster speeds the high back pressure gas finishes getting in just as the return stroke begins (3). At an excessively fast speed the high back pressure gas gets in on return stroke only just as the little ports are closed (4).

All types of compressors, whether wet or dry, single or double acting, horizontal or vertical, using ammonia or any other refrigerating agent, can readily be changed to multiple effect compressors, thereby increasing their compactness, economy, saving engine-room space, foundations, piping, oil, supplies and attendance. Multiple effect compressors of the Hercules or Boyle type are like Fig. 8. Multiple effect compressors of the Frick-York type have a piston a little longer than the stroke like Fig. 9, or can have the high pressure port governed by a positively operated valve like Fig. 10.

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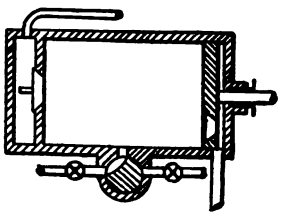

FIG. 10.

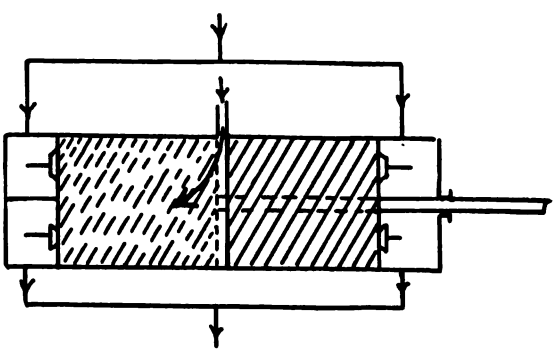

FIG. 11.

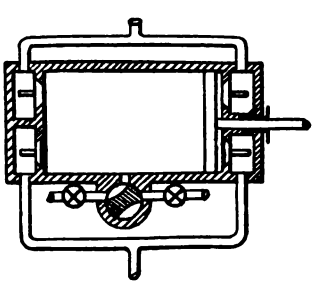

FIG. 12.

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Double-acting multiple effect compressors have the piston equal to the length of the stroke and the cylinder a little over twice the length of the stroke, like Fig. 11, or can have a positively operated valve like Fig. 12.

The additional quantity of refrigeration that can be done by the M. E. C. is obtained by dividing the absolute high back pressure by the absolute low back pressure and subtracting 1 from the product. For example, what is the increase in capacity by changing a compressor that operates at 5 pounds back pressure into one to operate M. E. C. at 5 and 25 pounds gauge back pressure? Adding 15 pounds to these back pressures to make them absolute pressures gives $5+15=20$ and $25+15=40$, $40 \div 20=2$, $2-1=1$; here 1 represents 100 per cent. gain in capacity. Had it been $44 \div 20$, the result would have been 2.2, and $2.2-1=1.2$, or 120 per cent. gain in capacity. The regulation of the high back pressure is perfectly automatic, and as simple to regulate as is any expansion valve. The higher back pressure is governed by conditions and fixes itself to suit the refrigeration to be done by it. If there is no refrigeration to be done at the high back pressure there will be no high back pressure, and up to the maximum limit the high back pressure will be higher or lower as the refrigeration required to be done by it is more or less. One non-M. E. C. requires more power to produce a given amount of refrigeration at a low back pressure than would be required by two non-M. E. C. doing the same refrigeration at two different back pressures, one of which is equal to the low back pressure before mentioned and one of which is a higher back pressure.

The friction load of any compressor is practically constant, whether the compressor is operating at one-fourth, one-third, one-half, three-fourths, or its full rated capacity.

The power required to operate the M. E. C. is less than that which would be required to operate two non-M. E. C. compressors doing the same total quantity of refrigeration at the two back pressures by at least the entire friction load of the high back pressure compressor, plus the power that would have been required to compress the low back pressure gas up to that of the high back pressure gas.

The power required to operate the M. E. C. is less than that which would be required to operate one non-M. E. C. compressor doing the same total refrigeration at the low back pressure by about the difference in friction of the necessarily larger machine so required and the friction of the M. E. C. plus the extra power required

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FIG. 13.

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to compress the gas that could have been handled at a higher back pressure, plus the power required to compress the low back pressure gas to that of the high back pressure.

The April and July, 1905, copies of *Ice and Refrigeration* have articles on the M. E. C., the July number telling of a test I made with a 14x32 M. E. C. Hercules type. Fig. 13 is a view of that compressor. In the test of the above-mentioned compressor the back pressures were 0 and 7 pounds and condenser pressure 147 pounds. The increase in capacity was 89 per cent. and the refrigeration was produced for 32 per cent. less power per ton than if two compressors at 0 and 7 pounds back pressure had been used, and for a similar compressor non-M. E. C. to have done an equal amount of refrigeration at 0 pounds back pressure would have required 68 per cent. more power per ton.

This test was of short duration, but was carefully made and all readings were checked by a disinterested party. The results obtained are so much in excess of my expectations that I hope to make another test in the near future to check the results. Until then I do not care to assert that such extraordinary results can always be obtained. However, the results mentioned are well within the bounds set by theory and may be accounted for on the supposition that the partial compression of the low by the high back pressure gas was without the generation of heat, and, moreover, that refrigeration was probably generated which made the mixture of gases more dense. The inertia of the rapidly flowing high back pressure gas may have been sufficient to cause more of it to enter the cylinder than one would have expected.

I changed a 15x32 inch Frick compressor in San Francisco to M. E. C. this year. But owing to the fire the nearly completed cylinders were so injured in the machine shops that by the time they were rebored and erected it was too late to make the test I intended to have reported at this meeting. The workmanship on these new parts was not what it should have been. I operated the machine M. E. C. to make ice and cool water in the forecooler and took some good indicator cards. Actual copies of a pair of such cards are seen in Fig. 14. In this test, at speeds as high as seventy-four revolutions per minute, the high back pressure gas had ample time to enter the cylinder through the little ports.

Compressor engines are generally large enough for the M. E. C., as they are put out by the manufacturers of non-M. E. C. machines. But if such engines prove to be too small to operate M. E. C., then their power can readily be increased by using higher boiler pressure

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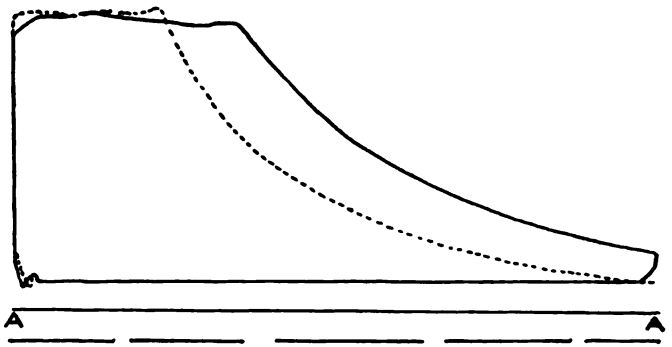

Eighty pound spring.
15″ x 32″ compressor.
Sixty revolutions per minute.
Condenser pressure, 150 pounds.
Suction pressure, 16 pounds and 24 pounds.

FIG. 14.

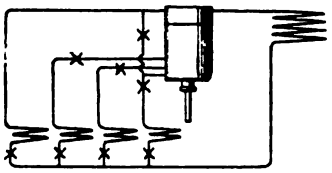

FIG. 15.

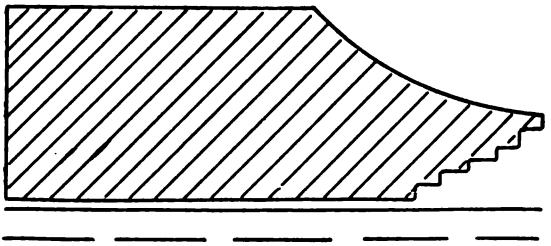

FIG. 16.

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or operating them condensing, or both, so that new engines will not be required in changing an old compressor to a M. E. C.

When the high back pressure of the M. E. C. is used on the piston rod end of the cylinder there is an absence of trouble from frozen packing and from ammonia leaking out on the rods. Furthermore, a dry compressor, that was, can operate M. E. C. with all the advantages of a wet compressor and none of its disadvantages. The M. E. C. can be used to advantage wherever the refrigeration is or can be done at two different back pressures, such as the following combinations: Chill rooms and freezers in packing-houses, fore-cooling water and freezing it in ice making, combination of can and plate ice making, cooling brewery cellars and Baudelot coolers, freezing ice cream and making ice, hotel and club refrigeration and making ice cream, cold storage and cooling living room, ice making and cooling air for blast furnaces, and numberless other combinations.

Moreover, the M. E. C. can have not only two, but three, four, five or six or more effects, Fig. 15. Such a compressor would give an indicator diagram like Fig. 16. The M. E. C. with six effects could do different grades of refrigeration at different back pressures as follows:

	Pounds, Gauge.
Plate ice	0
Can ice	15
Brewery	25
Forecoolers	35
Baudelots	45
Air coolers for blast furnaces or living rooms	60

The above gives a gain of 400 per cent. in the capacity of the compressor that made the plate ice in the above table, operating at the same speed and doing the extra refrigeration step by step, as above outlined.

DISCUSSION.

Henry Torrance, Jr.—I presume that, if there is any doubt about the gas going in through the little port quickly enough, the ports could be made bigger.

D. S. Jacobus—I would like to ask Mr. Voorhees whether, to get the best effect, there does not have to be a certain amount of refrigeration at each of the two pressures. Take the case cited where the back pressures are 29 and 18 pounds; would it not be necessary to have a certain relation between the refrigeration required at each of the pressures in order that the diagram shall be of the form shown in the figure?

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Gardner T. Voorhees—I am glad you asked that question, because I neglected to say that the high back pressure adjusts itself to the refrigeration it has to do. The 29 pounds was arrived at in this way: Twenty-five per cent. of the entire refrigeration required was devoted to cooling water in a forecooler. In other words, the cooling of the water amounted to 33 per cent. of the refrigeration required at the lower pressure. So by taking the absolute back pressure of 33 pounds, which corresponds to 18 pounds gauge pressure, and making the necessary proportions so that the increase in refrigeration is equal to 33 per cent., we get the result of 44 pounds absolute pressure, and subtracting 15 to bring it to gauge pressure gives the 29 pounds. The 29 pounds might have been 27 for less refrigeration, or it might have been 35 pounds for more refrigeration. The high back pressure would adjust itself automatically so that the ratio between the absolute low and high suction back pressures will be in proportion to the relative amount of refrigeration done. I do not know whether I make this plain. It is rather complicated to explain. One of the first things everyone seems to ask is, "How do you fix a certain pressure?" and I say that the high back pressure fixes itself.

L. Howard Jenks—In case the amount of work required at the higher back pressure, which you have taken at one-fourth of the total amount, is variable—that is, assuming that it is 20 per cent. or 50 per cent.—how would you arrive at the regulation that, with the same compressor, would give you the increased capacity? In other words, if you have to arrive at the exact proportion of the amount of work done at high pressure, and the amount done at low pressure, will not any cylinder, as adjusted under this system, only be good for that particular condition? As in practice the percentage varies very much, would not it be necessary to have some means by which it could be regulated?

Gardner T. Voorhees—That question is along the same line as that of Professor Jacobus and seems to be the point that is most difficult for me to make clear. If the compressor were used in a brewery, it could at a fixed speed cool the cellars of the brewery, and then by opening the expansion valves pick up the load of the Baudelot coolers, and then the Baudelot coolers could be shut off. Of course, the governor would alter the steam distribution in the steam engine, and the amount of ammonia evaporated would determine the pressure immediately, whether it is 25, 35 or 32 pounds.

Of course, there is a point above which you could not do a given amount of refrigeration; that is, there is a certain point at

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which you could not show any more than a given quantity of refrigeration at the back pressure, and if that point were reached it would be necessary to have a larger machine or to use some other method.

John E. Starr—In case the auxiliary valve were a rotary valve, or any form of valve to be moved by some moving part of the mechanism of the machine, would it not be possible to admit high pressure gas at different portions of the stroke and make a card something like a shoe?

Gardner T. Voorhees—I think the point made by Mr. Starr is very good, and he has spoken to me of something similar before. What he suggests would be possible, for instance, if the compressor, instead of having small ports at the bottom, had one of the valves which he describes, and if the proportion of the work were such that the method he describes could be used to advantage the port could open and shut at such a point as to give a card having a slipper shape and which I believe is Mr. Starr's point. Whether such an arrangement would possess any material advantage would be a question to be decided by a test.

Irving Warner—Did I understand Mr. Voorhees to say that a multiple effect compressor took less power than two separate compressors, doing the same work, friction eliminated?

Gardner T. Voorhees—I meant to say that the multiple effect compressor, by theory and proved by practice, requires less power to do a certain amount of refrigeration than could be done by two compressors operating at two back pressures, or can be done by one compressor operating at one back pressure.

Irving Warner—You drew three cards. Take the first one as being 100 per cent., what was the area of that second card running at the back pressure that would double the absolute back pressure, somewhere about 150 or 175?

Gardner T. Voorhees—I cannot go into this point without going into too many figures here. It is found by investigating a great many cases that the mean effective pressure of two diagrams is made up in this way. The mean effective pressure of one diagram, we will say, is a certain amount; the mean effective pressure of the other diagram of the two is another amount, and the power required for the compressors would be in proportion to the mean effective pressures and the area of cylinders—you admit that?

Irving Warner—Yes.

Gardner T. Voorhees—Then in that way you would get the power required by the two compressors. If you took the power

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required by the multiple effect compressor you would see that the power would be less, as shown by the card. That is, extra power would be required by two compressors in place of the multiple effect compressor.

Irving Warner—I should say that a little power would also be saved in case the work was done with two compressors. My argument is, whereas you have an area of 100 per cent., then the area of the second card is something greater, something like 175, I suppose, but is only on a cylinder of half the size, which has, say, 80 per cent. of the work.

Gardner T. Voorhees—I think I have the figures on the diagram.

Irving Warner—You add the extra area to the larger sized cylinder instead of adding to the smaller sized cylinder.

Gardner T. Voorhees—The mean effective pressure on No. 1 card was seventy and a half, and the mean effective pressure of the upper part of the card for the multiple effect was, I think, seventy-six. I won't attempt to go through those figurees, but I will refresh my memory and go through the problem more at length with you later on if you desire. At any rate it came out that the power required to do 33 per cent. more refrigeration was 19 per cent. more in that particular case. Whereas there was a gain of 33 per cent. refrigeration capacity, it required only an excess of power of 19 per cent., or required less power proportionally to do the extra refrigeration than to do the smaller or original refrigeration, and that point is borne out by the experiments I have made, showing that much better economy is obtained in practice than in theory, and that much more refrigeration is obtained than would be theoretically expected, and much less power is required by the multiple effect compressors than you would expect.

D. S. Jacobus—In considering the theoretical cycle, it seems to me that by employing two compressors, one working at one back pressure and the other working at the other, that, leaving out the friction, more economical results would be secured than with the multiple effect compressor. If the friction is included, however, I can see that the multiple effect compressor may be the more economical.

Henry Torrance, Jr.—It seems to me that you do not have to go into the indicator cards to tell that. A compressor will do more work at 30 pounds back pressure than it will at a low back pressure, and it will do it with less horse power per ton. You run the compressor at a low pressure and the gas comes in at the last

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minute; you get the work of both high temperatures and low temperatures done at the most economical rates; that is to say, at the high temperature. I do not see how you could combine two compressors and get the same result, because here you get the low pressure work and the high pressure done under the best and most economical conditions. So with the multiple effect compressor, as I would figure it, you would do just as much work as you would do with two separate compressors, but you would do it at the rate at which you would do the high pressure work. Is that right?

Gardner T. Voorhees—No; if you leave out the question of the friction then you would lose the most important item. Many combinations of indicator cards always seem to show that the mean effective pressure was only very slightly less than the added mean effective diagram of the two other compressors, but in each case that I tried, as I remember, it was slightly less, but the great gain was, as I say, in overcoming the 25 per cent. friction load of the other compressor that would be used if non-M. E. C.

Irving Warner—I think Professor Jacobus made clear the point I was trying to bring out; namely, that, friction eliminated, there is really a loss in the multiple effect. With friction considered I have no doubt that it does better work, but you can see that when the auxiliary valve opens there is a rush of gas, and whenever there is a rush of gas there is a loss some place.

Gardner T. Voorhees—It may appear so, but it is a fact that there is a gain in combining the compressors, and it cannot be taken exception to when you get down to hard tacks and compute the area of the diagrams, get your horse power and your different pressures and other data, and add them up, and then you will find that there is a slight gain and not any loss even without friction of the second machine.

Edgar Penney—Do I understand Mr. Voorhees to say that he can increase the amount of work done by the compressors without increasing the friction? Is not the friction due to the load?

Gardner T. Voorhees—I think I will be borne out by some who are here in making the statement, not too broad, but general, that the friction of a compressor with a given condensing pressure, no matter whether it is doing 50 or 150 tons of refrigeration, is very nearly a fixed quantity; that is, it is very nearly a constant.

Edgar Penney—I understand that in the steam engine the amount of steam used per horse power decreases with the load. Now, you have not got this confounded with that, have you?

Gardner T. Voorhees—No; what I mean is this, that the com-

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pressor turning over, doing no refrigeration whatsoever, requires a certain amount of power to turn it over at a certain speed, and that amount of power, usually called the friction load, is somewhere near uniform.

Edgar Penney—That theory of getting something for nothing is nearly radical or revolutionary.

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No. 26.

WATER JACKETING OF AMMONIA COMPRESSORS.

By R. L. Shipman, Ithaca, N. Y.

(Member of the Society.)

Professor Denton, in his memorable paper presented to the American Society of Mechanical Engineers in 1890, records the data from a single test which he made without having water in the jackets of the compressor cylinders, and the discharged gas ran only a few degrees higher than when water was used; but this seems to have attracted very little attention, being incomplete and overshadowed by so much data of seemingly greater value. It is probably safe to say that nine-tenths of the operating engineers to-day think it impossible to operate an ammonia compressor at any considerable head pressure without the use of water in the jackets, or under the conditions of wet compression. It is probably also safe to say that nine-tenths of the jackets in use are a source of waste rather than a saving. The object of this paper is to throw some light upon this subject and show, if possible, the true function of the water jacket of the ammonia compressor, and to venture a few suggestions for improvement.

Considerable attention has been given to this subject at the test plant of the York Manufacturing Company, York, Pa. The subject presented itself rather accidentally, as follows: During a series of five tests, to determine the relative merits of wet and dry compression, the method of procedure was to run a series of different discharge temperatures, the change in discharge temperature being obtained by changing the percentage of humidity of the suction gas. The method of changing the humidity in this series of tests was to expand liquid ammonia into the suction lines just outside of the compressor cylinders. The conditions specified for this series of runs were suction pressure 15.67 pounds, gauge; head pressure 185 pounds, gauge; and 70 r. p. m. of compressor; the gas to leave the cooler slightly superheated. The temperatures of the discharge gas were to be 95.4°, 150°, 200°, 250° and 300° F. All went well until the last test was reached, when, with all liquid excluded from the suction lines, and with gas entering the compressor considerably superheated, the temperature of the discharge gas refused to go as

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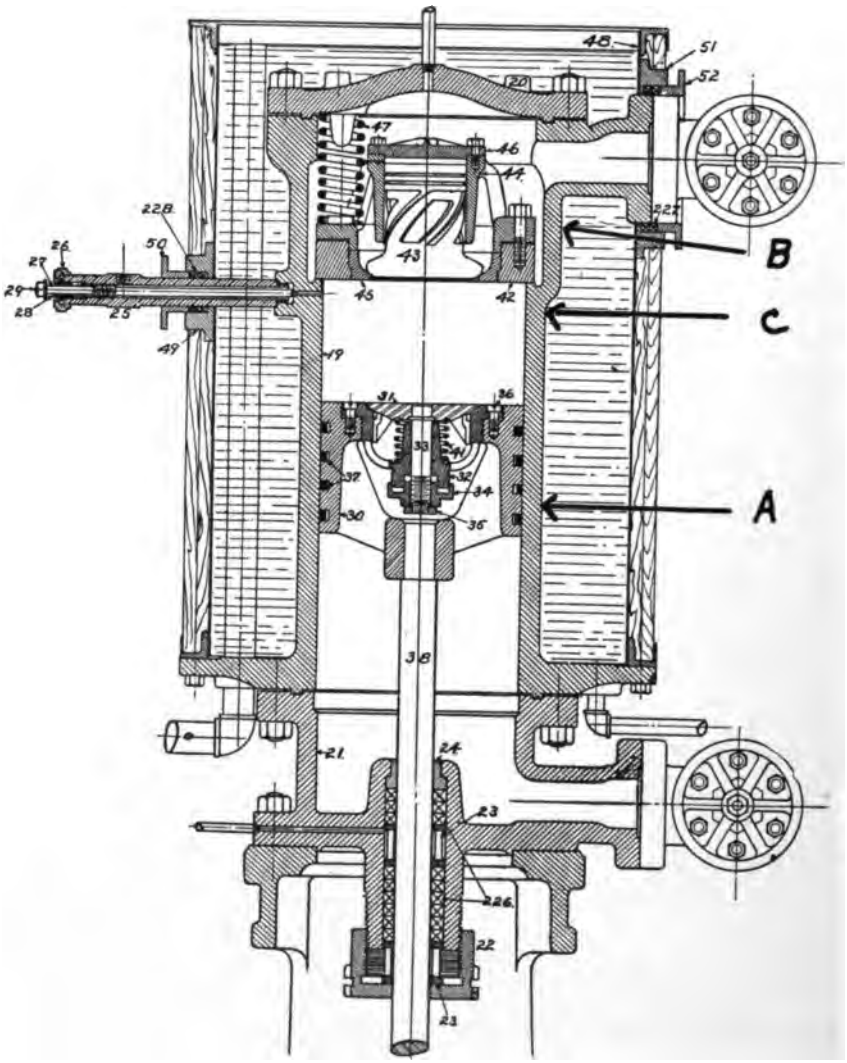

FIG. 1.—SECTIONAL VIEW OF COMPRESSOR IN TEST PLANT OF YORK MANUFACTURING COMPANY.

19 Compressor barrel.
20 Compressor top head.
21 Compressor lower head.
22 Compressor stuffing-box nut.
23 Compressor stuffing-box lantern gland.
24 Compressor stuffing-box bushing.
25 Indicator valve body.
26 Indicator valve packing nut.
27 Indicator valve stem.
28 Indicator valve stem gland.
29 Indicator valve stem wrench nut.
30 Ammonia piston.
31 Suction valve.
32 Suction valve cage.
33 Suction valve stem.
34 Suction valve cushion nut.
35 Suction valve lock nut.
36 Round head screws for cage.
37 Snap rings.
38 Piston rod.
41 Suction spring.
42 Safety head.
43 Discharge valve.
44 Discharge valve cage.
45 Discharge valve seat.
46 Discharge valve cap.
47 Springs for safety head.
48 Water jacket body.
49 Indicator valve stuffing-box.
50 Indicator valve stuffing-box gland.
51 Stuffing-box for discharge nozzle.
52 Stuffing-box gland discharge nozzle.
226 Packing for ammonia piston rod.
227 Packing for water jacket discharge nozzle.
228 Packing for water jacket indicator nozzle.

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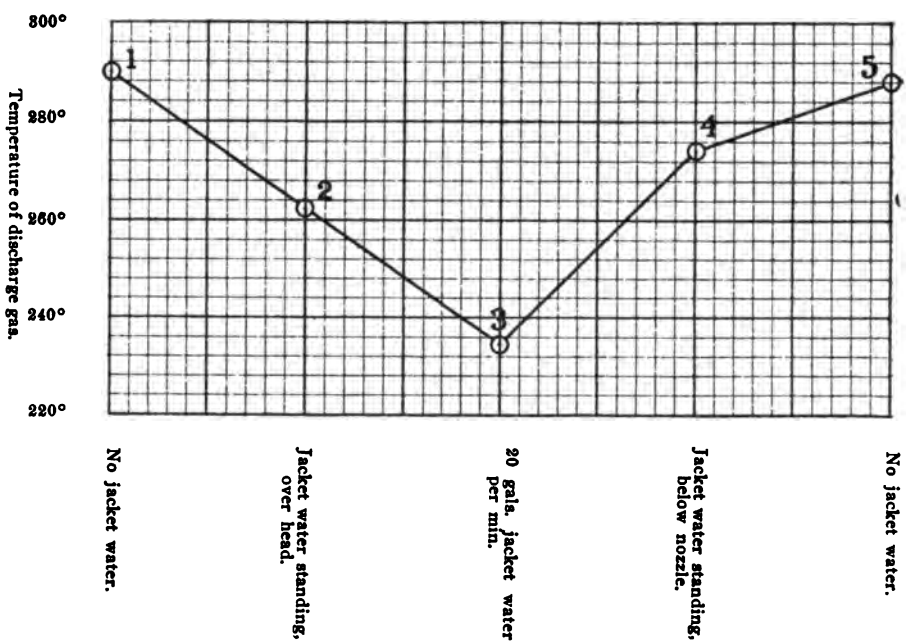
high as 300°, running at an average of 289.3° for the test of six hours. This seemed to be a considerable surprise to all concerned, as a much higher maximum temperature of discharge gas was expected for the conditions set for the test. Many tests were subsequently run without jacket water and also with varying quantities of jacket water, several of which are quoted from in this paper.

Fig. 1 shows a section of the ammonia cylinder and jacket as used for the tests of Plate I and Plate II.

Plate I is merely a graphical log showing the discharge temperature of the refrigerating medium for varying conditions of

PLATE I.



Suction pressure, gauge, 15.67 lbs.
Condenser pressure, gauge, 185 lbs.
Speed compressor, 70 r. p. m.

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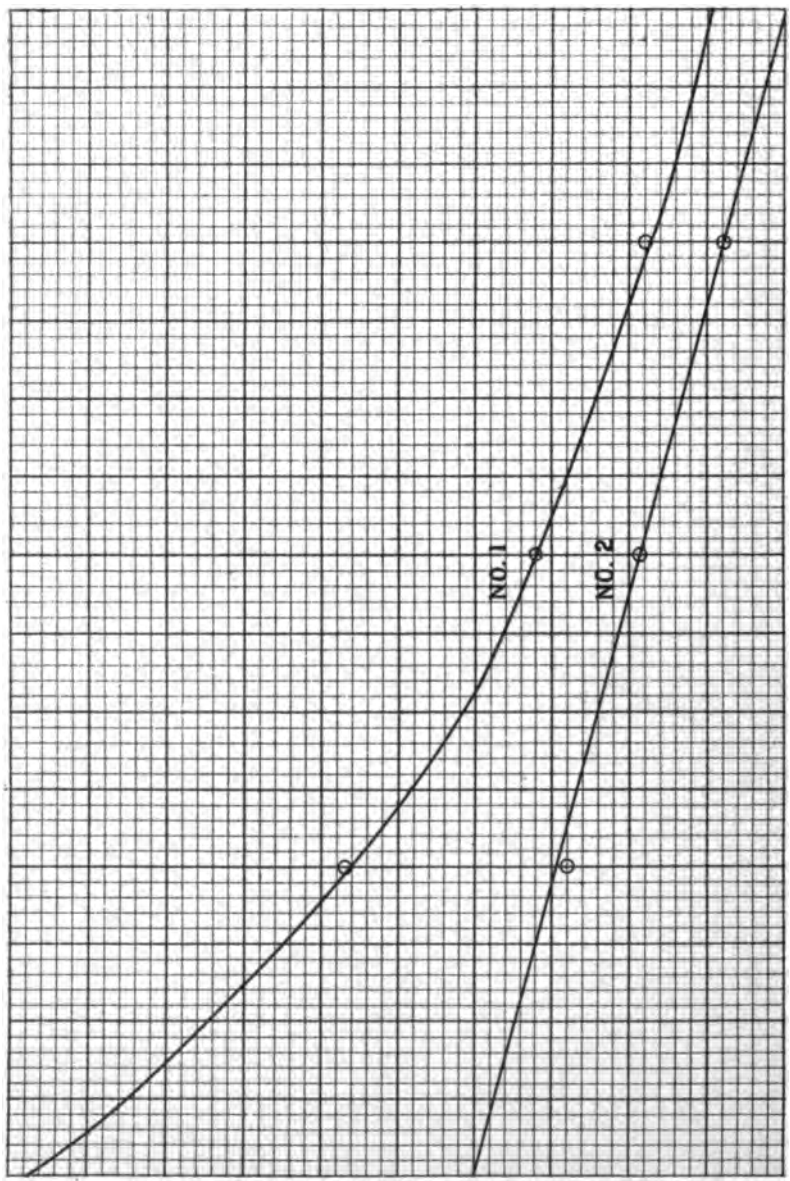
PLATE II.



Upper curve, without jacket water.
Lower curve, with jacket water.
Condenser pressure, gauge, 185 lbs.
Speed of compressor, 80 r. p. m.

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jacketing with a compressor speed of 70 r. p. m. The tests from which points No. 1 and No. 5 of this plate were produced were run under practically the same conditions without jacket water, and it is to be observed that the discharge temperatures are practically the same —a little less than 290°. The discharge gas temperature of 262°, point No. 2 of Plate I, was obtained with the jackets filled until the top heads were just covered, no water being admitted except to replace that lost by evaporation, which was very little. The average temperature of the water in the jackets for this condition was about 180°, and, of course, considerable steam could be seen rising from the jackets at that temperature. The discharge gas temperature of 234°, point No. 3, was produced by the use of about 20 gallons of jacket water per minute, or about half a gallon a minute per ton of refrigeration, which is 25 per cent. to 50 per cent. of the amount of condensing water that would ordinarily be used, and which when used is a great waste of jacket water. It is to be observed that the temperature of the discharge gas is still considerably above the temperature of boiling water, and the machine attendant often makes the mistake of turning on a little more jacket water to protect the compressor from harm from this presumably high temperature.

Many engineers of large experience have stated to the writer that it has always been their impression that jacket water should be run in large quantities to protect the compressor. The writer was recently in a large plant where the jacket water was run in such quantities that it was leaving the jackets nearly as cold as it went in. The water costs five cents per thousand gallons. The plant is a large one, and the engineers in charge of it are of no mean quality. The writer can look back over his own experience of several years as an operating engineer and see that jacket water was most invariably used to a large excess. Another recent observation was that of a large air compressor plant in which about as much water was being run through the jackets as through the cooler. The water was flowing from the jackets nearly as cool as it went in, while the water which went through the coolers increased about twenty degrees in temperature. The compressors were large and ran at a piston speed of about 500 feet per minute. Under this condition of operation, the jacket water could do practically no good and might as well be dispensed with. These illustrations go to show the importance of such data as are given in this paper.

The discharge gas temperature of 274°, point No. 4, of Plate I, is the temperature produced by having jacket water standing in the jackets below the discharge nozzle of the compressor. (See letter

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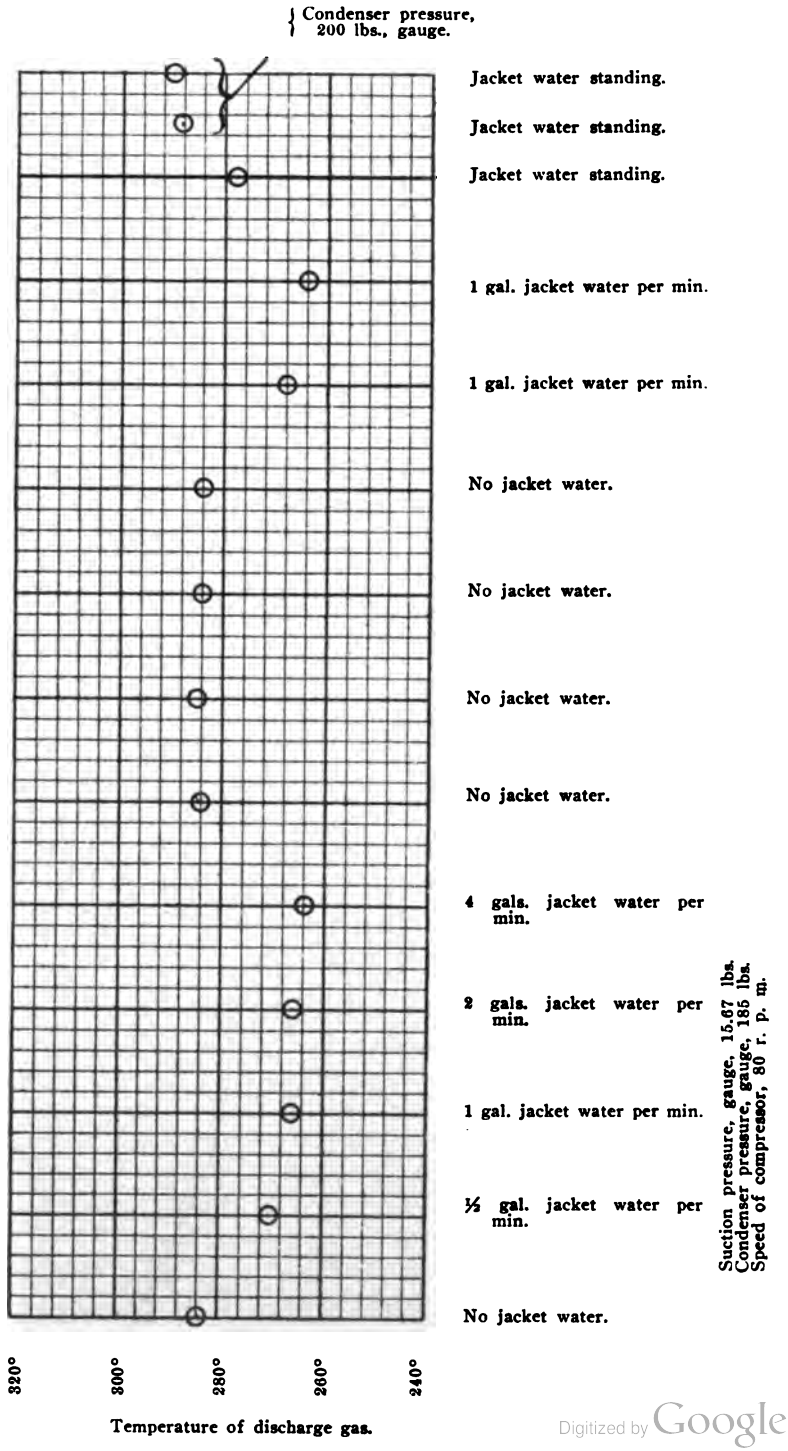
PLATE III.



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B, Fig. 1.) This was about 12 inches below the overflow and about 4 or 5 inches above the seat of the false head. The temperature of the water in the jackets under these conditions stood at about 150° and the evaporation was very slow.

Plate II is made up from data gathered from a series of tests at a constant head pressure of 185 pounds, gauge, and back pressures of 10, 20 and 30 pounds, gauge. In this series of tests, one test was made without jacket water and then repeated with jacket water at the rate of about one gallon a minute. The upper curve of this plate shows the temperatures without jacket water, and the lower curve, which is nearly a straight line, shows the temperatures of the discharge gas with jacket water. These lines diverge toward the lower pressures owing to the facts that less ammonia is handled at these pressures, and that the temperatures run higher, allowing the jacket water to take out a larger percentage of the superheat of the gas. The upper curve remains practically constant for all speeds of the compressor and for any quantity of clearance. This curve will not be elevated by a discharge valve sticking open. It will be elevated by leakage, especially toward the lower pressures, and with leakage the elevation will be much greater for the lower speeds. This curve is a very important one and deserves a great deal of study, but as the writer expects to produce a chart of such curves at an early date it will not be discussed further at this time.

An important observation made concerning the conditions of jacketing for the tests of Plate I and Plate II is that the jacket water comes in contact with a large area of the compressor cylinder above the seat of the false head, which acts only as a condensing surface, and does not act as effective jacket surface. In the tests of Plate I and Plate II a large percentage of the rise in the temperature of the jacket water is gathered from this surface rather than from the effective compression surface of the cylinder. After the gas has been unavoidably pumped up to this high temperature, why not take advantage of the radiating surface between the compressor and the condenser to dissipate a large percentage of this superheat and by this radiation save condensing water?

For a further investigation upon the subject of jacketing, the regular jackets were removed from the cylinders and temporary jackets were substituted that extended only half way down the cylinders, and they extended up only to the lower side of the discharge nozzle of the compressor cylinder, from A to B, Fig. 1. This was the condition of the jackets for the tests of Plates III and IV.

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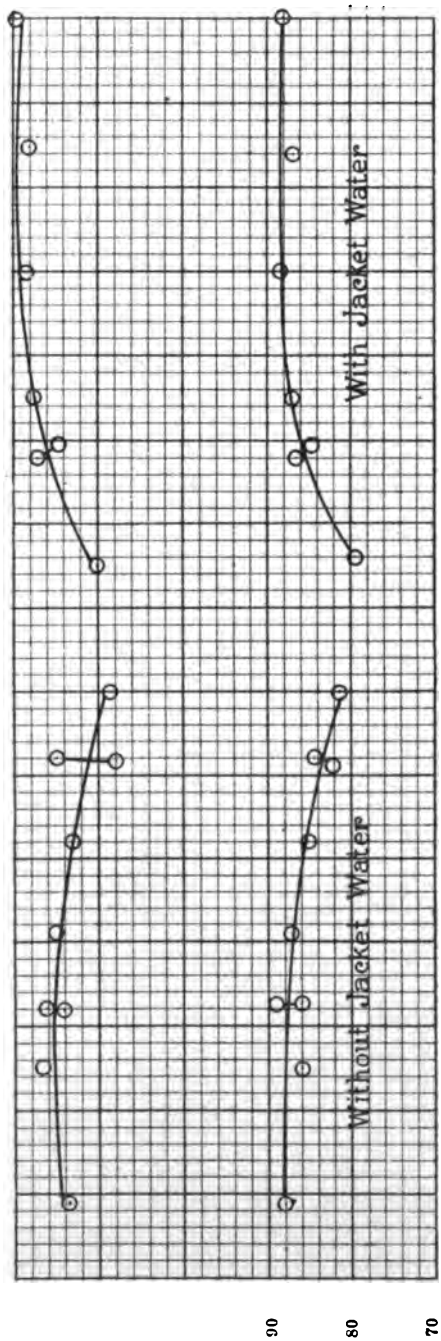
PLATE IV.



Revolutions of compressor per minute.

Pounds of ammonia handled per 1,000 cubic feet of piston displacement.

In the upper curves the abscissæ represent absolute suction pressure—115 divisions equal 30 lbs.

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Plate III is for varying quantities of jacket water, and is quite self-explanatory. It is to be observed that the jacket water has very little effect upon the temperature of the gas for this condition of jacketing even at the moderate speed of 80 r. p. m. of the compressor—less than 250 feet piston speed. Then, what would be the effect of jacket water at piston speeds of 600 to 800 feet per minute? From this plate it is to be especially observed that jacket water, in quantities of more than 1 per cent. of the condensing water used, produces no material change in the temperature of the discharge gas. A good rule for the use of jacket water is to use it in such quantities that the temperature when it leaves the jacket will not be much below 100° F.

A close inspection of the data from many tests shows no increase in the efficiency of the compressor by the use of jacket water.

Plate IV is interesting in that it shows the amount of ammonia handled per unit of piston displacement for different speeds of compressor with and without jacket water, and no gain is shown from the use of jacket water.

After having made many tests on the vertical single-acting compressor, the York Manufacturing Company built a horizontal double-acting compressor of the same bore and stroke as the vertical cylinders and hitched it tandem to the steam cylinder that had been used to drive the vertical compressor, and repeated many of the tests that had been made on the vertical compressors.

The effect of jacket water on the vertical single-acting compressor, as has been shown, is almost too small to be of any use, but the effect of jacket water in the case of the horizontal double-acting compressor is of less value, as the heads cannot be jacketed, and by the nature of the construction the jacket is around the coolest portion of the cylinder, as can be seen from Fig. 2. It has been generally supposed that on account of the less efficient condition of jacketing the temperature of the discharge gas would be higher for the double-acting compressor, but this supposition has not been borne out by tests, as is shown by Plate V. While in this plate the range in temperature of the jacket water is but little less than in the preceding plates for the same amount of jacket water used, there are two conditions of these tests on the horizontal cylinder, and if they had been kept the same as in the case of the vertical cylinders the range in the temperature of jacket water would not have been nearly so great as here shown. That is, the temperature of the water entering the jacket of the horizontal cylinder was 43°, as against 70° with the vertical cylinders, and the speed of the

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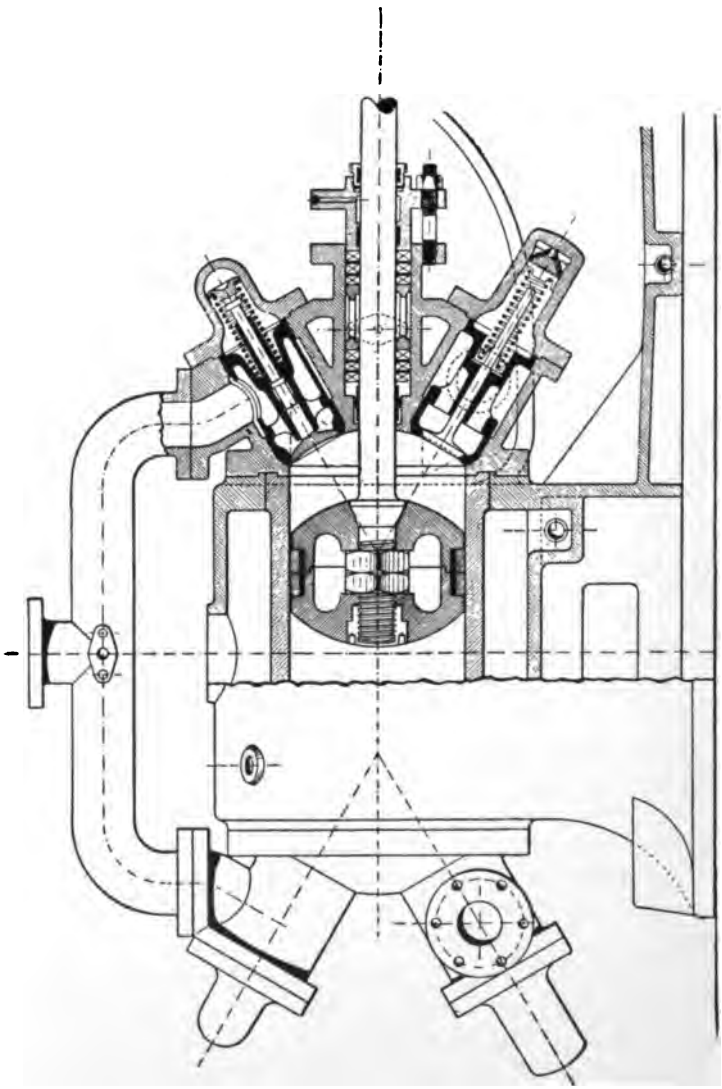

FIG. 2.—SECTIONAL VIEW OF A HORIZONTAL DOUBLE-ACTING COMPRESSOR.

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horizontal compressor was about 60 r. p. m., as against 70 to 80 r. p. m. of the vertical cylinders. In the case of the horizontal compressor the jacket water, little as it was, left the jacket at about 70°. As the temperature of the engine room was 85°, it can be seen that a large percentage of the rise in the temperature of the jacket water was due to heat absorbed through the outside walls of the jacket from the air in the engine room.

A very significant fact in connection with the tests on the horizontal compressor was that when running without jacket water the air in the jacket was found to run at about 110°. This shows that the jacket water could not be expected to do much useful work.

Two of the most significant observations bearing upon this subject are as follows:

1. When the vertical single-acting cylinders were run without jacket water at low speed the cylinders would get warm the full length of the stroke, but as the speed was increased the warm temperature would recede up the cylinders, the lower ends becoming cooler, and when operating at the speed of 125 r. p. m. the cylinders became so completely cooled that one's hand could be held on the cylinder at about the point C, Fig. 1, very near the end of the stroke.

2. When running the vertical cylinders with partially wet compression, so that the temperature of the discharge gas was 150°, the frost line on the outside of the cylinders ran within 4 or 5 inches of the end of the stroke, showing that the heat of the cylinder above the false head is not conducted very far down the cylinder.

The reasons for the inefficiency of water jackets can probably be found in the following explanation: The heat interchange between the ammonia and the cylinder walls is probably very near equal. That is, during compression the gas becomes heated and gives up a certain amount of heat to the cylinder walls, but during the suction stroke the cold gas sweeps over this heated surface and washes off, so to speak, nearly all of the heat left on that surface during the compression stroke, the volume of the gas being swelled in proportion to the heat thus absorbed. From the explanation it would follow that the heat interchange would decrease as the time allowed for it decreased, that is, toward the higher speeds; the swelling of the volume of the gas would be less and the cylinder would take a heavier charge per stroke, and thus we might expect the cylinder to handle more gas per unit of piston displacement toward the higher speeds. This condition has been shown quite conclusively to be the case.

It is a well-known fact among operating engineers that after

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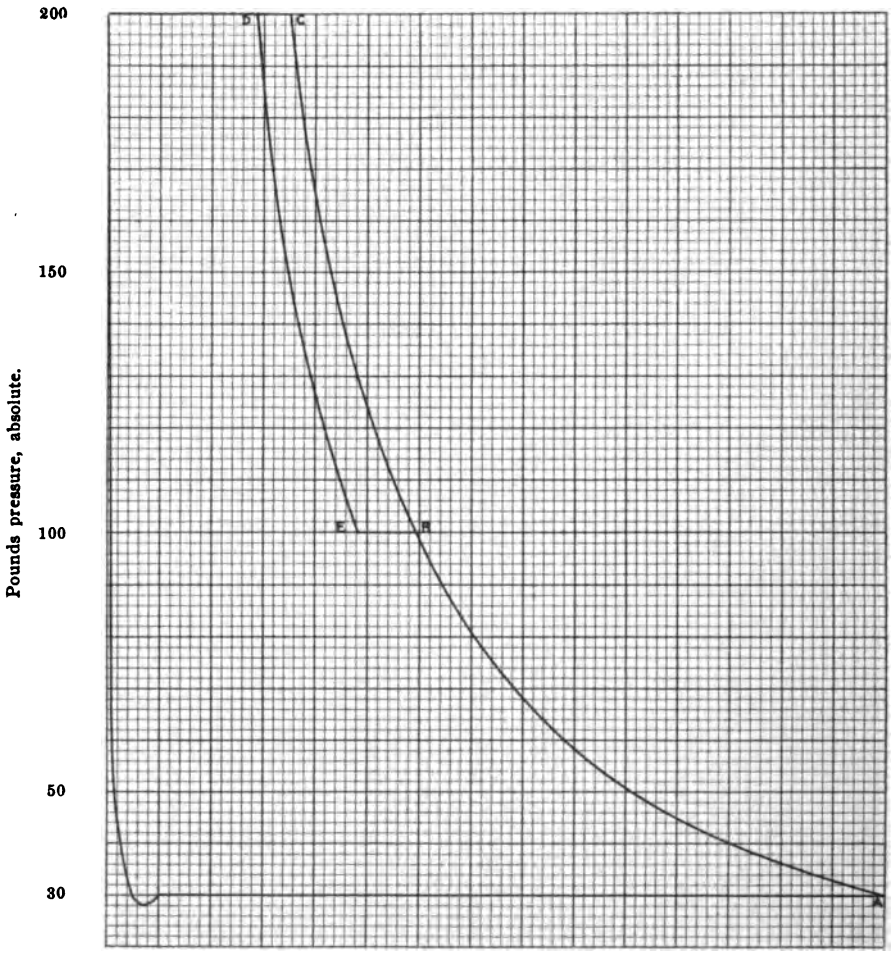

FIG. 8.

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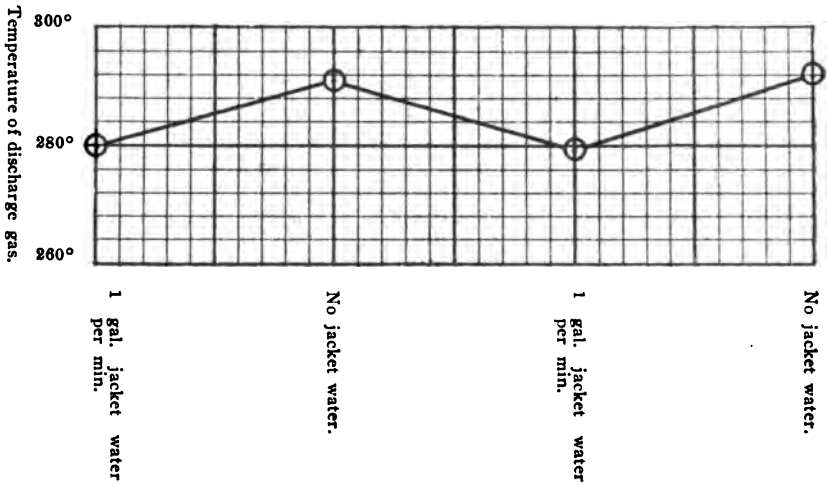
PLATE V.



Suction pressure, gauge, 15.67 lbs.
Condenser pressure, gauge, 185 lbs.
Speed of compressor, 60 r. p. m.

a compressor has been shut down for a time, sufficient to become thoroughly cooled, the gaskets, especially lead gaskets, will begin to leak when the compressor is started up. If any of these joints are covered with jacket water the leakage will probably go on for a long time without detection, while if the joints are uncovered the leak would be detected at once.

There is a well-grounded belief among engineers that ammonia decomposes during the high temperatures of single-stage compression. But this is an open question, and one rather difficult to determine experimentally. However, since we cannot expect protection from jacketing, and to get it by wet compression means a much greater loss than a saving, we must look for the protection in some other condition. Probably the most natural recourse would be to the multiple-stage compression. By multiple-stage compression we not only prevent the excessive compression temperatures, but a considerable work of compression could be saved. While the writer has not yet had an opportunity to make exhaustive tests on multiple-stage compression of ammonia, it certainly seems advisable to adopt two-stage compression in many cases. For example, Fig. 3 exhibits a card with adiabatic compression curves and shows some results of pumping ammonia single stage and two stage from 30 pounds pressure, absolute, to 200 pounds, absolute, the corresponding gauge pressures being about 15.5 pounds and 185 pounds,

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which are the pressures commonly in use during the time that most refrigerating is done. The line ABC is the compression curve for the single-stage compression, and the temperature of the discharge gas for this condition, as has been shown, would be about 290°. With two-stage compression, the gas being pumped to about 85 pounds, gauge, in the first stage, the temperature at the end of this stage would probably be about 180°. Then its temperature could be reduced in an intercooler to about 60°, thereby reducing its volume about 18 per cent. During the second stage the temperature of the gas would probably rise to about 160°. These two discharge temperatures are reasonably low, and there would be absolutely no reason for placing jackets on the cylinders. If at any time, with this arrangement of compressors, it becomes necessary to pump at a low suction pressure, as in pumping out, or as is sometimes done in charging, it only becomes necessary to decrease the discharge pressures to protect the machines from harm from excessive temperatures. In Fig. 3 the curve ED is the compression curve for the second stage, and the work saved by the two-stage compression would be represented by the area BCDE, which, in this case, represents about 9 per cent., and the heat taken from the gas by the intercooler represents about the same percentage of the total heat, while it has been shown that the jackets work within 1 per cent., especially at speeds at which compressors should be operated. When we deduct from that meagre amount the heat that would be radiated from the heated portions of the cylinder, if they were exposed to the draughts of the engine room, and also the amount of heat that the jacket water absorbs from the air of the engine room, the jacket has very little usefulness left. With this method of construction it is highly probable that the intercooler would be less expensive to construct than the jackets, and would probably do ten to fifteen times as much good.

DISCUSSION.

L. Howard Jenks—I would like to know whether under the conditions of these tests the compressor was run in every case with what is known as wet gas.

R. L. Shipman—There was none whatever. The gas coming in was superheated 10° to 20°.

John E. Starr—I would ask the professor if there were any cards taken during these tests, or in relation to them, showing the difference of the horse power as shown in the compressor and the actual amount of heat taken out as shown by the range of the water in the jacket.

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R. L. Shipman—I do not get your question, Mr. Starr.

John E. Starr—Of course, some heat was taken out by the jacket water which would be measured by its difference in range; and as the amount is small I desire to know if there is any check between the amount of heat taken out and the horse power as exhibited by a card.

R. L. Shipman—You never see any difference in the horse power, in the compression curve, and in the amount of ammonia used. In this case of a double-acting machine, the jacket water went in at the extremely low temperature of 46°, and at the low rate of 6 gallons an hour. It went out at a temperature of 60°, a room temperature of 75°, and, the outside of the compressor not being insulated, a considerable amount of heat would be taken up from the surrounding air.

John E. Starr—That would figure less than thirteen thermal units per minute.

R. L. Shipman—There is another rather significant item: The temperature of the air in the jacket space of the double-acting machine ran in one case 112°, no jacket water; in another case 108°, no jacket water.

Gardner T. Voorhees—I desire to express my thanks to Professor Shipman for that paper, and anyone who read the little book that I wrote five or six years ago—"Indicating the Refrigerating Machine"—will recall a diagram and statement that I made that is borne out by Professor Shipman's account. I believe that the compression line in any compressor varies very little from the adiabatic line; that is, that the true compression line compares almost with the adiabatic line; and as I understand Professor Shipman, his tests bear that out almost directly.

Henry Torrance, Jr.—Did Professor Jacobus ever test Mr. E. D. Leavitt's air compressor, where they injected large quantities of water to cool the air?

D. S. Jacobus—I have tested air compressors where water was injected for the purpose of lowering the compression curve. To get the maximum cooling in an air compressor a spraying device must be used which divides the water into a very fine spray. To accomplish this the water must be at a high pressure. With such a device the compression line may be made lower than the adiabatic or so that it approaches the isothermal line.

Henry Torrance, Jr.—You get it down quite a little?

D. S. Jacobus—Yes.

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Henry Torrance, Jr.—You get it down much more than with the water jacket?

D. S. Jacobus—Yes.

Henry Torrance, Jr.—Then the old method of injecting oil ought to be of advantage?

R. L. Shipman—In any case when the liquid is admitted to the cylinder, as in the case of wet compression or that of injecting water into an air compressor, the heat interchanges between the walls of the compressor, and the air or the gas is much higher than when you admit only the superheated gas. The heat interchanged between superheated gas and the surface is very much less than the heat interchanged when liquid comes in, and that explains why when injecting water in the air compressor we do not get the gains we expect. Another point in connection with this jacketing that I omitted to insert in my notes is that when we were running partially wet compression with a discharged temperature of 150° we had frost on the outside of the cylinder wall within four inches of the seat of the false head.

Edgar Penney—When you were handling wet gases?

R. L. Shipman—I said we were running partially wet compression in that case. I stated in the introduction that this condition of jacketing came on rather accidentally. We were running perfectly wet compression; then we changed the temperature of the discharged gas by increments of about 50° by changing the amount of liquid injection. We could change that at will.

Edgar Penney—You did not mention what was the quality of the gas that flowed from the refrigerators.

R. L. Shipman—It was slightly superheated, so that we could tell how much heat came from the cooler.

Edgar Penney—Didn't you allow liquid to flow out to some extent?

R. L. Shipman—No; not in this series of tests.

Edgar Penney—Do you mean to tell me that in one of your tests without jacket water you had frost?

R. L. Shipman—No; except when we were running partially wet compression. When we ran with 15 pounds suction pressure and 185 pounds head pressure, the gas entering the compressor at a temperature of about 20°, the discharged temperature never went higher than 280° to 290°.

Edgar Penney—How did your theoretical temperature correspond to the actual or discharge temperature; how did they correspond with the table; how close?

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R. L. Shipman—When we were running perfectly wet compression the discharge temperature was practically the same as that given in the tables.

Edgar Penney—How much superheat was there with no water in the jacket?

R. L. Shipman—In the case of the double-acting machine 10° entering the compressor.

Edgar Penney—In the single-acting machine?

R. L. Shipman—About the same.

Edgar Penney—What is the method of measuring the conditions and work of the machine?

R. L. Shipman—Have you not read an account of the test plant of the York Company? You will find it in the June, 1906, issue of *Ice and Refrigeration.*

Edgar Penney—Describe your methods.

R. L. Shipman—That is rather a long story. The most important features of a plant of this sort are the arrangements for measuring the different quantities. To measure the liquid ammonia, three large receivers of about 1,000 pounds' capacity each were suspended from three independent platform scales, the receivers being submerged in a tank of water and counterweighted so that only the weight of the liquid they contained was supported by the scales. These receivers were connected by perfectly flexible connections. During a test one receiver was receiving liquid from the condenser, the liquid being carefully weighed every fifteen minutes. Another receiver was supplying ammonia to the expansion valve, this ammonia also being carefully weighed every fifteen minutes; thus the ammonia was weighed twice in the circuit. The third receiver was filled with ammonia, and on the next change of receivers this one was cut in on the expansion side, the empty receiver being cut in on the condenser and the one just filled from the condenser being left idle until the next change of receivers.

The weighing scales were checked up from time to time with United States standard 50-pound weights with different loads on the scales. (See general plan herewith.)

The suction pressure was measured by a mercury column, a standard barometer being placed in the plant and read once an hour, corrections being made for changes in barometric pressure.

The brine was measured by the displacement of the circulating pump; this pump was a triplex, power-driven, outside packed type, so that the only slip in the pump was through the valves. Many

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careful calibrations showed that this slip was very small, and that the pump made an excellent brine meter.

During the most careful tests temperatures were taken by mercury thermometers that had been calibrated by the United States Bureau of Standards, care being taken at all times to use high grade and accurate thermometers.

Water meters were used for measuring the water to the ammonia condensers, the meters being carefully calibrated from time to time.

A stroke counter was used to determine the speed of the compressor.

The test plant consisted of a York standard vertical single-acting machine with two vertical ammonia cylinders 9 inches by 12 inches, with horizontal engine of the Corliss type.

Many types of coolers and condensers were eventually tested, some six hundred tests having been run on the plant, the plant having been intact some three and one-half years. Also during these tests a horizontal double-acting cylinder of the same bore and stroke as the single-acting cylinders was placed tandem to the steam cylinder, the connecting rods to the two vertical cylinders being disconnected during the time that the double-acting cylinder was in use.

The special value of the data from a test plant of this character lies in the comparative results from tests run in series, only one condition being changed during the series.

Edgar Penney—Then you could follow the compressor work through all its phases?

R. L. Shipman—Entirely.

Edgar Penney—That is what I wanted to find out, whether it was a "rob Peter to pay Paul"?

R. L. Shipman—No; it is only to develop high-grade work.

Edgar Penney—You made up your heat charts?

R. L. Shipman—Yes.

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No. 27.

CONTRACTOR'S WARRANTY VERSUS ENGINEER'S SPECIFICATIONS.

By John C. Wait, New York, N. Y.

(Member of the Society.)

In discussing this subject is will be necessary to consider the general subject of warranty. One cannot go far toward covering so broad and technical a subject as warranty, but before taking up the subject of this paper it will not be out of place to dwell briefly upon some of the general features of warranty.

A warranty is a statement or representation made by a seller at the same time and as a part of the contract of sale, having reference to the title, the character, quality, efficiency, durability, stability or condition of the goods, article, machine or plant sold, and by which the seller promises or undertakes that certain facts are or shall be as he represents them. Time may or may not be an element of such warranty. The warranty is express when created by apt and explicit statements, oral or written, of the seller, and it is implied when the law derives it by implication or inference from the transaction or the relative situation or circumstances of the parties.

A warranty is treated as a collateral contract, and if it be not given or made prior to or at the time of the sale it must be supported by some consideration, the same as any other contract. It is not a condition as regarded generally in the United States, and a breach of it may be compensated in damages, the action being based upon the contract. The breach of a warranty is to be distinguished from a fraud in that respect.

A warranty given at the time the sale is made is founded upon the price as a consideration, or upon the giving of the contract of purchase to the seller. If the warranty be given subsequent to the sale it must be founded upon some consideration, as one dollar, or it will be invalid.

It is a rule of the law that in a certain class of cases the seller is held to warrant the title or quality or existence of the property sold and of which he assumes to have knowledge or about which he has the means of knowledge, or even concerning which it is a policy of

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the law to charge him with knowledge; yet at the same time the purchaser is required to inform himself about those things which he has a fair opportunity of ascertaining.

Under this rule it is held that where an article is made and offered for sale there is an implied warranty of the fitness of such article for the uses for which it was intended. This may be established by a comparison with other articles or machines or by custom and usage in a particular trade, but it will not ordinarily be extended to the quality of general goods and merchandise which are open to inspection and examination.

This implied warranty is frequently excluded by an express warranty, but the warranty expressed must be of the same kind or character as that which it is sought to imply. Thus an express warranty of title will not exclude an implied warranty of quality, and vice versa. With this principle in mind it would therefore seem a reasonably prudent undertaking for a seller to give such a warranty as he is satisfied he can meet and which will be acceptable to the purchaser.

The word "warranty" should be distinguished from the word "guaranty." You may warrant a machine or plant, but you may not guarantee it. A man may guarantee the payment of a debt of another, or he may guarantee the performance of a contract, but he should not undertake to guarantee the quality, efficiency or duty of a refrigerating plant.

Warranties, as made by engineers, and especially of this Society, are probably those of capacity, efficiency, duty and endurance; also those of quality, character and kind, and those of comparative usefulness, as those equal or superior to others or per sample, and those to maintain and keep in repair. Generally, except as above set forth, warranties will not be implied nor will their application be extended. If one warrants a machine in a particular manner it precludes an express warranty as to like character and precludes any extension by an express warranty.

A warranty should be regarded as an extra consideration to the purchaser and as an additional burden to the seller. It should not be assumed except for an extra price or in exchange for some benefit to the seller. It should not be recklessly assumed or granted without estimating its cost. A warranty may have far-reaching effects and bring results not anticipated by the seller. It may not only burden him with the ordinary, first-thought-of obligation to repair, perfect or replace the machine or plant, but in case of accident causing personal injuries or death it may bring a burden of afflic-

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tions not dreamed of at the time of the sale. It is asking a good deal of a manufacturer or of an engineer to warrant the sufficiency or capacity of a machine. Such a step requires a careful consideration not only of the mechanical and scientific features but also of the pecuniary obligations and legal complications that may arise if the warranty fail. The varying conditions presented, the adaptation of plant to the space and relative positions even of the appliances, the necessity of utilizing engines, boilers and machines already at hand, lead, I believe, to results not always anticipated.

Warranties should be in writing, and if given subsequent to the sale they should recite a consideration or be under seal. If not in writing and to be performed within a year they may be held void and of no binding effect, being under the statute of frauds. The liability should be defined and limited, and it would seem to be good practice to include in your contracts of sale and installation that the purchaser waives all claims for damages on account of non-performance of machinery sold, or waives all claims on breach of warranty except such as are assumed expressly, thus limiting the liability to taking out the machine and refunding the money, or to making good any defects that appear. This is better than to give a general warranty and ultimately be mulcted in damages for a warehouseful of poultry or game or for the loss of extraordinary prospective profits, which may or may not have been realized, but exist in the fancies of witnesses who are economical of the truth.

A purchaser may lose a warranty and a seller be relieved therefrom by an acceptance and by failure to complain within such a reasonable time as the purchaser shall have discovered any defects, or that the machine was not of the efficiency or capacity for which it was sold. This may not apply, however, to latent defects that would not reasonably be discovered.

It seems that where a warranty is pleaded as a defense to the recovery of the purchase price, the burden of proof is upon the seller to show that the goods corresponded with and fulfilled the warranty. It has been generally so held. The breach of warranty must be pleaded by the purchaser and the warranty must be shown.

A warranty, it seems, is not negotiable or assignable, and protects only the purchaser with whom the contract is made. It may, of course, be made to accompany and attach to the article or machine warranted, but this is not usual.

We now come to the subject of this paper, viz., "Contractor's Warranty versus Engineer's Specifications."

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As already remarked, it is asking a good deal of a manufacturer or engineer to warrant the efficiency or capacity of his design, but it is asking a great deal more when a manufacturer is asked to follow the plans and specifications of an architect or engineer, as of a municipality or of a hospital, morgue or market; and especially when such plans and specifications have been prepared on the presumption that said architect or engineer knows the business, or when they have been prepared with the counsel and advice of some other manufacturer who has special devices and apparatus which are designated and required to be used and which are adapted particularly to the plant or equipment of such manufacturer. Then it is that the warranty of results becomes a serious question. In municipal work and work for large cold storage warehouses, public officers and produce men frequently require warranties as to the capacity, efficiency and duty of their plants. Sometimes certain types of machinery are required, and the bidder has to adapt his machines to those of others. Occasionally this is impossible, whether from design on the part of the public officials, who usually are required to award the contract to the lowest bidder, or through the ignorance of the produce men, their architects or engineers. If the former, then the difficulties are increased by the desire and wish of the public officials or the architects or engineers to steer the job to a particular person or company. This is no unlikely case, but on the contrary is a situation that frequently has to be met. In such a case the question arises who is responsible—the municipality or owner who prepared and furnished the plans and specifications, or the manufacturer who warranted the results, and this is the situation that is presented under this title of "Contractor's Warranty versus Engineer's Specifications."

Taking first the usual case between a private owner and the manufacturer, in which we have only to deal with the warranty versus the specifications and plans, the cases are many but conflicting.

As a general proposition of law, it may be stated that when an owner prepares plans and specifications setting forth the general detailed manner in which the structure is to be built he warrants the sufficiency of such plans and specifications. This has been held in the case of an arch that fell, and equally so for a structure, also for an oven. It was not so held for a bridge to be built requiring caisson foundations in the Thames River, the performance and completion of which were prevented by the tidal currents. This, however, was not a case of plans and specifications for the structure, but where the

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owner undertook to describe the method by which the structure should be erected, which method, the courts maintained, had been adopted and vouched for by the contractors. That was an English case. It may be stated generally in this country that the owner who furnishes plans and specifications warrants their sufficiency.

The engineer, however large his general powers may be, will be limited by those conferred by the contract. He may not allow things which the specifications forbid, nor can he require what the specifications do not require and the plans show. He may not determine things not expressly included within those enumerated and described. A power to determine all things arising under a contract, or in the prosecution of work under the contract, does not authorize him to determine whether or not the contractor broke his contract, or what damages his employer suffered thereby, or what is or is not extra work, or what the sub-contract includes, which is described in the original specifications—unless, indeed, these powers are specifically conferred upon him.

The engineer may not change the specifications and accept concrete of different proportions than those specified, nor can he classify materials differently than is required, nor adopt or make up intermediate classifications, nor waive requirements as to how foundations shall be prepared.

When plans and specifications describing the class or character of the materials and the manner or method of doing the work have been prepared, and the specification or contract concludes with an express statement that the said work "shall be water-tight" or "in such manner as to be water-tight" or to secure a water-tight cellar, sewer or cistern, or that the whole job shall be completed in accordance with said specifications so as to make a water-tight job, it has been held that if the materials and work conformed to the specifications and plans and to the directions of the engineer, as required by the contract, the contractor had done all that was required of him; that a warranty will not be imposed by implication under such circumstances.

This doctrine has been held in many cases in the United States and the several State courts, especially of the Middle and Eastern States. It has been so held in the case of a reservoir costing several hundred thousand dollars, and which leaked so badly when completed that it could not be put to the uses for which it was intended. It has been so held for a cellar floor, and of cisterns, sewers and other like work, and the same doctrine should hold likewise for machines and plants. A manufacturer should only be required to show that he

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has built the structure or machine according to specifications and plans and the requirements of the engineer and inspectors.

A contrary decision seems to have been made in the courts of California, where a manufacturer contracted to furnish an ice plant built according to certain specifications and who guaranteed its sufficiency. It was held that he was liable for its failure to do the work, though the specifications were furnished by plaintiff, and even though an efficient ice plant could not be constructed by following them. This case must have been determined upon the ground that the manufacturer had adopted the specifications furnished, or that he warranted the efficiency of the ice plant independent of such specifications. A somewhat similar decision has been made in the State of New York, in a case where the original contract contained a warranty, the court holding that such warranty could not be relieved from by alterations in the specifications or plans or by instructions and directions varying therefrom. This case was one of a basement floor which the plan showed was to be 6 inches thick, but which did not indicate the materials to be used. The specifications required the floor to be water-tight and a warranty that it should be so, and the specifications and drawings were declared to co-operate. The court held that the thickness shown in the drawings (6 inches) was controlled by the specification to make it and warrant it water-tight, and that the contractor was bound to make the floor water-tight even if it were necessary to make it thicker than 6 inches.

It seems unreasonable to allow an owner or his engineer or architect to specify arbitrarily details of a machine or structure, the character of the materials employed and the sizes and shapes of its parts, and to then impose the responsibility of its good behavior upon the manufacturer, and such a practice would appear to be extraordinary. It is, however, a frequent occurrence, if not a common practice, and it is not confined to the manufacturer of machines. Architects of this city frequently specify the character of a cornice or other part of a structure, and designate its thickness, size and manner of erection and support, and then require the contractor to warrant that it will stand a load of 150 pounds per running foot, or that a flooring shall stand a load of 100 pounds per square foot after a prescribed fire test. After the same plan, a heating contractor is required to warrant that the apparatus will heat the rooms of a building at 70 degrees in zero weather, when the boiler is already installed and its capacity fixed.

In such circumstances it is puzzling and requires more than ordinary decision of character to determine whether one will bid or

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not, and, having bid and having been awarded the contract, whether he will bend to the will of the architect or pursue such a course as will enable him to fulfill the wararnty. The situation is not, perhaps, so serious when the work is being done for a private party as when it is being done for a public corporation, as a municipality, and the manufacturer or builder has given bonds for the faithful performance of his work.

Contracts with municipalities are usually founded upon advertisements, public lettings and awards to the lowest bidder. That frequently presages a low price. The architect or engineer of the municipality may have certain favorites, and if he has not, the politicians have. Certain goods or apparatus have been described or favored in the specifications and plans, and the work is not infrequently cut out for a particular party. This stifles competition and is expressly prohibited by the laws and the charters of municipalities, and it may come within the prohibition against the purchase of proprietary or patented articles. It may be apparent to the successful bidder that a certain refrigerating plant was intended to be secured for the bureau or department, and it may be even fairly apparent that there was collusion between the manufacturer or engineer and the public officers of said department in the preparation of the specifications and the contract. The successful bidder may find himself tied up by specifications practically requiring a competitor's apparatus and an auxiliary warranty on his part that it shall fulfill and perform certain conditions as to capacity, efficiency and duty. In this case what shall he do? Shall he abandon the specifications and fulfill the warranty, or shall he fulfill the warranty and repudiate the specifications?

It is my opinion that he has a good fighting chance to do either, especially on municipal work. He may defeat public officers in their attempts to hold up his payment or in their refusal to certify because he has not strictly followed the specifications, and if he has followed the specifications he may escape the warranty by showing that he has fulfilled and performed as required, and that the city or its agents warrant the sufficiency of their designs.

Whether the owner or the contractor be liable upon the warranty or for the perfection of the work, of the efficiency or duty of the plant, it must be conceded that the practice of preparing specifications in detail and requiring the contractor to follow them, and then exacting a warranty as to the efficiency, duty or perfection, should be condemned in engineering circles, and that no self-respecting engineer or architect will tie a contractor or manufacturer to

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detailed specifications and then require him to warrant the results. Such a practice should not be countenanced.

DISCUSSION.

Edgar Penney—I do not rise to discuss this interesting paper, but to make a few remarks on some architects who, with their first appearance as experts in installing refrigerating machines and ice plants, begin by inviting free-for-all competition and are loaded up with specifications by possibly all the competitors, who have laid themselves out to make a complete standard specification. These architects afterward make up a specification by selecting striking features from all those submitted and issue it as their own, like the native Chinaman who was making a pair of trousers from a European model—he copied it, patch and all. This prerogative of the privileged architects accounts for many of these seeming inconsistencies, and that I know to be a fact.

John E. Starr—There is one thing that I think a good many of us have had to contend with, and that is the question of how far the warranty goes in the direction that the apparatus shall be fit for the purpose for which it is intended. I think, from more or less experience as a witness in the courts, on breach of contract more than any other, the question comes up as to what is a 10-ton machine, or what is a 100-ton machine, or what is a 50-ton machine. Testimony on one side shows that the machine is not a 50-ton machine, and that on the other side that it is a 50-ton machine, each figuring correctly, but on different back pressures or on different methods of taking heat up, and on altogether different planes.

There have been endeavors to get a ruling that the machine should show 50 tons of refrigeration, taking up heat on a plane suitable for the purpose for which it was intended; that is to say, if the machine had a lot of low temperature work to do, involving low back pressures, that the tonnage must be figured on the low back pressures, but I have never seen a clear-cut ruling on that point. I would ask Mr. Wait how far that doctrine goes, as to the warranty that the apparatus shall be fit for the work for which it was intended.

John C. Wait—Usually those are questions of fact and not of law. Questions of fact are to be determined by the jury, and they may be determined differently by any two succeeding juries in the same court on the same day. It depends upon the versatility of either side, on the testimony of the expert witnesses largely, and on the ability with which the lawyers handle their witnesses.

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As a rule I do not take such engagements, but I am to be a witness to-morrow to facts as well, and I have been asked to determine stresses and a lot of other things in connection with the case. You know a lawyer's description of an expert has been defined as positive, comparative and superlative; in other words, liar, thundering liar and expert witness. Of course, I have not had any such experience as that, because I am particularly careful in choosing my experts, but the question of implied warranty as presented to the court usually is: What is the custom; what is that which establishes a standard in a profession, in the factories and among manufacturers? That must be established by the manufacturers themselves who, when they come before the court to establish that to the satisfaction of a jury, become witnesses. Being a question of fact and not of law it will always be variable. If a standard is to be established after that it must be done by the societies and not by the courts. I do not know of any decisions in point.

Oswald Gueth—A warranty, as I understand it, may be considered a collateral contract, where special consideration would have to be proven. Does Mr. Wait know of any case where, in any breach of warranty, the absence of a consideration has been set up as a defense?

John C. Wait—I have not any at hand in my own practice, but I am sure I can give the gentleman any number of them from the books. He must understand that where there is a collateral warranty it must be given subsequent to the sale. You can even take this position: You may undertake to build a man's house, according to the plans and specifications. Neither the plans nor the specifications show that the walls are to be painted. The owner afterward says, "Why, look here, I thought those walls were to be painted?" You, as contractor, say you do not intend to paint the walls, to which the owner replies: "That won't do; those walls will have to be painted." Then you say, "Well, I will paint the walls." You build the house and complete it, except painting the walls. You do not have to, because there is no consideration given for the promise to paint the walls. The same thing would apply to a warranty given after the contract was completed, but for no additional consideration. Cases of that kind are frequent. If the gentleman likes, on my return from up the State where I am going to attend a case, I will furnish him with cases on this point. Had the specifications required the painting of the house the contractor would have had to do it, but he promised afterward, and since the promise was not made for any consideration it was not a valid or binding agree-

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ment; it was a promise for nothing, which is not a promise that can be enforced. You could make promises all day long, and except for the moral obligation they would not amount to anything. You can promise to build a man a million-dollar house in exchange for a canary bird, and it will hold, but you cannot promise anything where there is no equivalent. The court cannot shut its eyes to the fact that there is no equivalent.

Here is a familiar phrase in written contracts: "The purchaser, for and in consideration of one dollar, to him in hand paid by the seller to the purchaser, and in consideration of one dollar to him in hand paid by the purchaser to the seller, agrees to do so and so." There was never anything more frivolous; I give you a dollar and you give me a dollar, and in consideration of these two considerations we undertake to do certain things; but the law cannot undertake to decide that those two considerations are not equal. I give you a dollar; you give me a dollar, and we are even.

L. Williams—If I, as a purchaser, wish a contractor to give me a warranty as to the quality and workmanship of a machine, and if I put a clause in the contract that in consideration of the awarding of the contract the contractor shall warrant the said material and workmanship to be the very best quality, that would stand in law?

John C. Wait—Unquestionably.

L. Williams—Without any further consideration at all being given?

John C. Wait—You need not even recite that in consideration of the given contract; you need not recite any consideration after the price, but simply state "I warrant this machine" in the bill of sale or at the time of signing the contract. The law will find that the price given was the consideration, but if after the sale was contracted you say at that time, "I promise to warrant it," you must be given a dollar or some consideration to support it.

L. Williams—That would imply that it was a separate agreement?

John C. Wait—Yes; but you must not let any seal come in on your name. If it were a sealed contract you would not have to have any consideration; a sealed instrument implies a consideration. Every contract that is sealed is considered to have a consideration, even if it is a marriage contract. The seal takes the place of the consideration.

Oswald Gueth—It applies only to a contract that is not sealed?

John C. Wait—Any simple contract that is not sealed.

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Gardner T. Voorhees—I would like to ask a question: The ordinary form of boiler specification and contract is printed and is filled in. Say it is agreed to furnish a boiler of such and such a make, having so many square feet of heating surface, and this, that and the other, to do so many horse power, say 350 horse power, to evaporate so much water at 70 pounds pressure with feed water at 100° F. The boiler is erected and there is no question of the stack not being large enough or the setting not being right. The whole job is done right. The purchaser has a number of auxiliary machines operated from his boiler; and it is difficult to determine the amount of steam that these auxiliaries use; and he says to the seller, "I do not believe your boiler is doing 350 horse power." There is a deadlock, and the purchaser says, "It is for you to furnish an expert and make a test and show that the boiler is making 350 horse power, and that it is evaporating so much water." My question is, under these conditions would the seller of that apparatus be compelled by law generally—I do not mean any specific State law—to stand the cost of that test, to prove to the purchaser that the boiler did evaporate so many pounds of water and was producing 350 horse power; or must the purchaser have that test made at his expense to prove that the seller did or did not give him what he required?

John C. Wait—I think that question can be answered by what was in my paper, as to whether he should satisfy the purchaser. Before he would get a judgment he would probably have to satisfy the court, because where a warranty is pleaded by the purchaser in an action the burden is on the seller to establish his warranty. How else could he establish it except by a test? I would therefore say, if it could not be established in any other way, that very likely the burden would fall upon the seller. I had that case happen in South Nyack on a street sewer. We were to leave the sewers clean so that a ball one foot in diameter could go through them. The question came up as to who should supply the ball and who should put it through.

L. Howard Jenks—I had a specification that was drawn up by an architect wherein he specified that the "NH_3 fittings" must be made of steel, and the amount of "H_2O" that would be supplied—he could not even say water—to the ammonia condensers should be so much; and yet he followed that up by saying that notwithstanding these specifications the contractor must be responsible for the performance of the machine, and that everything must be done to his satisfaction, naming himself in the specification.

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John C. Wait—That must have been a city contract.

L. Howard Jenks—Under those circumstances the warranty had to depend upon the satisfaction of the architect. If the architect was not satisfied I do not see how one could determine whether the warranties had been complied with or not.

Gardner T. Voorhees—Referring to my boiler proposition, suppose that the seller came into court and produced his books and said that he had sold hundreds of boilers which, with that proportion of heating surface, had made that amount of horse power. Would not that be taken as sufficient evidence that it was not necessary for the seller to have a test made, and would not the test be waived where no specific guarantee to make a test had been made at the time of selling the boiler?

John C. Wait—I think the gentleman is right. That is a matter of the proof that would satisfy the judge and jury, and might be adopted. The seller might simply call two or three refrigerating engineers to show that in other cases under similar conditions the boiler had supplied 350 horse power, and that would be sufficient. Of course it would incite the other fellow to bring in three other kinds of engineers to show differently.

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No. 28.

INSULATION.

By Junius H. Stone, New York, N. Y.

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A mere outline of this subject is all that can be given, but, putting the essential features in their proper prominent places, the details which are necessarily omitted for want of time and space will suggest themselves. Attention is so frequently centred on detail, to the neglect of underlying principles, that for once the reverse of the process may be salutary.

There is, without doubt, room for improvement in the methods of insulating cold storage plants, and as the value of first-class insulation is generally admitted the subject is of practical interest. It is remarkable that products of the animal, mineral and vegetable kingdoms are put forward as fulfilling all requirements of good insulators, and it is fortunate that although they differ widely in value there is a sufficiency of distributed merit to prevent monopoly.

Before entering upon the consideration of these materials it is necessary to have clearly in mind the general factors upon which a decision as to the value of any one of them should be based. These factors may be stated as, first, cost, direct and indirect; second, durability or freedom from deterioration in service; third, efficiency or value as heat retarders.

Direct cost does not require comment; the indirect cost does, because it is out of sight, and that usually means out of mind. Expenditures classed under this head are continuous, amounting yearly to a large sum. Hence its importance, and a special reason for spending valuable time upon it is that it affords the only sure way of arriving at the value of one method of insulating as compared with another.

It is proper to include under the head of indirect cost the following items: Cost of refrigeration supplied to remove the heat which passes through the insulation; pro rata depreciation of machinery, that is, the proportion of it which the refrigeration supplied to make good the losses through the insulation bears to the total refrigeration produced by the plant; insurance so far as it is affected by the insulation; interest upon the cost of the insulation; depreciation of the insulation.

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It is unnecessary to defend the propriety of these items, as they speak for themselves. Their careful tabulation, as they bear on two or more competing forms of insulation, will often show surprising results as to real cost. Things are not always what they seem.

Having considered the question of cost, the next factor of prime importance is durability, and in cold storage construction this means, first and last, ability to resist moisture. In every cold storage plant we produce abnormal conditions, are in a state of siege, so to speak, with Nature as our adversary, struggling to break in and restore uniformity of atmospheric conditions in that particular locality where we have outraged her sense of the proprieties by making a little winter of our own in her good old summertime. She neither rests nor sleeps, and the visible sign of the success of her continuous assaults is moisture. It must not be forgotten that difference in temperature means difference in pressure, and consequently the warmer external air, with its moisture, is always pressing in wherever the smallest crack or opening permits. In the nature of things no piece of human construction can be perfect; hence moisture will penetrate, to a greater or lesser extent, every form of insulation that can be erected. The more complex its structure the more apt it is to take up moisture in quantities sufficient to cause its deterioration, and if the insulating material itself has large capillary attraction the spreading of the moisture throughout the structure is hastened, with a continually increasing loss of efficiency and decay. It is therefore clear that for durability the simplest construction, with fewest joints, and materials that do not absorb water readily and are free from capillary attraction, should be chosen.

The third and last prime factor that requires attention is efficiency. A marked change in general opinion as compared with the views held ten years ago is noted. At that time what may be called open constructions were the rule, large air spaces in series, usually of wood construction, though sometimes of hollow tile, the insulation proper being from 10 to 16 inches thick. These are now the exception instead of the rule, solid constructions 4 to 7 inches in thickness being favored, with a marked saving of space.

This change in opinion is due to the better knowledge we now have of heat transmission and the resulting conviction that large air spaces are apt to be worthless, and also to the attitude of the underwriters. The high percentage of fires and their severity in cold storage buildings as compared with other warehouses are matters of remark even by the layman, but the fact is that the old type of hollow wooden insulation is responsible both for their frequency

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and destructiveness. With up-to-date solid insulation, the cold storage plant is less liable to burn than any other type of storage building.

Generally speaking, the efficiency of any material as a non-conductor of heat is in direct proportion to the amount of entrapped air it contains compared with its bulk. Hence the lighter its weight the better insulator it will be. The still air is the essential thing, and any material that has a tendency to take up moisture, thereby displacing the entrapped air, must lose a large part of its efficiency in service should faulty construction permit moisture to enter. Ability to resist moisture is therefore as important from the standpoint of efficiency as from that of durability. In fact these two qualities are so interdependent that whatever affects one affects the other.

There is a sad lack of exact knowledge as to the intrinsic efficiency of the insulating materials in general use. "Tests" of all sorts there are in abundance, but unfortunately they generally emanate from interested sources, are made under diverse conditions and by methods as far apart as the poles, and naturally the results are flatly contradictory.

In the absence of data more applicable, there is one series of tests that may be fairly considered as helpful. These are the tests made by Professor Norton at the Massachusetts Institute of Technology, Boston, in 1898. They cover all the materials in general use as cold storage insulators, and are unquestionably impartial, being made by the order and for the information of the New England Mutual Fire Underwriters. They were run under uniform conditions and the quantitative heat measurements made electrically, which insured accuracy, and the results were carefully checked by duplicate tests. These facts made them valuable as indicating the relative standing of the various materials as heat retarders, but they did not reproduce cold storage conditions, being made at a high temperature and with a wide range of temperature difference. Hence they do not afford data as to quantitative heat transmission through cold storage constructions. They give a line on relative values, however, and for this reason, in the absence of anything better, Mr. John Levey has tabulated their results in his valuable pocket-book entitled "Refrigeration Memoranda."

It is encouraging to note that the technical schools of the country show an increasing interest in artificial refrigeration and are installing experimental plants from which in time we may reasonably

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expect an authoritative placing of insulating materials in their exact order of efficiency.

Remembering that any insulator to be efficient must be kept dry, and that the ease or difficulty of doing this should have a prominent place in any calculation, we may say, in the absence of exact knowledge, that the insulating materials in general use, namely, hair and other felts, the various mineral wools, and cork, are all efficient. As the Kentucky colonel said of the various brands of whiskey, "Some are better than others, but they're all good." The same kind words cannot be said of the old-time wooden constructions, "boards and air spaces," so called. The only point that could ever be made in their favor was their cheapness, and with the increasing cost of lumber that argument is losing its force.

So much for the basic factors—cost, durability and efficiency. As a corollary, a few remarks are in order upon the salient features, good and bad, of the insulating materials in general use, for, as Captain Cuttle would say, "The bearings o' these here observations lies in the application on 'em."

Beginning with the animal kingdom, there are as its only representatives hair and wool felts, the latter being but little used. With them may be considered the vegetable fibre felts, of which there are several. When dry, these are excellent insulators, and, being made in rolls of varying widths, up to 10 feet in some cases, have certain uses for which they are peculiarly well fitted. The insulation of refrigerator cars is one of the largest of these, and the interlining of dwelling houses, which is a form of insulation, should give them an almost unlimited sphere of usefulness. The marked increase of comfort and reduction of fuel bills which their use affords, coupled with their low cost, make it a matter of certainty that they will come into general use along these lines. For ordinary cold storage insulation they are handicapped by the readiness with which they take up moisture, and, particularly in the case of the animal felts, thereupon become very offensive. This objection does not apply in the case of refrigerator cars, for usually their life is short.

At present the mineral kingdom is represented by mineral or rock wool alone. There are several brands of this familiar material upon the market, both in the loose form and in compressed blocks. Their quality is excellent, far superior to the English make, though England is the home of these goods and uses proportionately much more of them than does the United States. English mineral wool of average commercial quality will pack 20 to 30 pounds per cubic foot, which is far too heavy. In Great Britain specifications fre-

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quently call for the packing to be "not less than 15 pounds per cubic foot," but seemingly it is not thought necessary to limit the top weight. Here 12 pounds per cubic foot, when properly packed, would be the top weight permissible, and there are American installations that run under 10 pounds per cubic foot well packed. The goods which show such a result are of the very highest grade. Good quality mineral wool when dry is an excellent non-conductor of heat, and in view of this fact, and of its cheapness, it is to be regretted that keeping it dry is a matter of marked difficulty on account of its high capillary attraction. Moreover it has little structural strength, even in the compressed block form, and therefore its proper erection requires special care and attention. In spite of these drawbacks it has many friends in the United States, and is one of the leading insulating materials in England. It should be remembered that London pays carpenters only twenty-one cents per hour (nine shillings per ten-hour day), while New York pays sixty cents, and consequently an amount of labor can be expended on careful construction work there that would be impossible here.

Exception to the statement that the mineral kingdom is represented among insulators solely by mineral wool may be taken by those who favor the older German brewery practice of using asphalt or pitch between brick walls. As to this it may be fairly said that the method is obsolete, both in the United States and in Germany, and that among the younger brewery architects it would be difficult to find one who endorses it. Pitch is not a good heat retarder. Its weight, 85 pounds per cubic foot, proves that it cannot be, and for damp-proofing, a thin coat, say one-eighth of an inch, well applied, is just as effective as an inch or more. It is fast falling into its proper place as a valuable material for damp-proofing work, but not as an insulation *per se*.

Coming now to the vegetable kingdom, there remain to be considered paper, lumber, and last, but not least, cork. The vegetable felts have already been mentioned.

As to the insulating papers in use, they have an important place, similar to that of pitch, as a damp-proofing course in good forms of insulation, but should not be considered as insulators. Paper constructions have been built, the air spaces being formed in series by erecting inch battens between successive courses of insulating paper, and, when carefully built, they have proved efficient when new. They are distinctly dangerous as fire risks, for they offer unlimited harboring places to rats. The tendency of these vermin to carry dropped matches into their nests and to start fires in

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the attempt to enjoy a frugal lunch is well known. It would be difficult to imagine a construction better fitted to insure the total destruction of a building where fire had once started than these pine and paper flues, and this ever-present danger is a sufficient reason for confining insulating papers to the very important task of excluding moisture from the insulation proper.

If the statement had been made fifteen years ago that within that time we should see lumber insulation, the good old "boards and air spaces," practically banished from up-to-date cold storage plants, the author would have been regarded with suspicion, as probably harmless, but certainly "off." The statement would have been literally true, and the result has been brought about partly by pressure from city building departments and boards of fire underwriters, and partly because lumber when in hollow cold storage constructions is necessarily exposed to its worst enemy, dry rot, and the resulting destruction has compelled a change. It has been a "survival of the fittest." The origin of dry rot is supposed to be the decomposition of the sap in lumber that gives certain fungi a starting point from which their growth destroys the wood fibres, reducing them in time to dust. A moist, stagnant atmosphere will produce dry rot most easily, and the warmer it is the quicker it will appear.

It will readily be seen that in the old-style air-space construction the lumber forming the air space farthest from the cold room is exposed to the exact conditions favorable to this disease. At some points the warm, moist outer air will inevitably find an entrance, and, as dry rot is apparently infectious, the trouble spreads from a few isolated points until the entire structure decays, and so, between the underwriters and dry rot and its own low efficiency, wooden insulation has had to go.

Considering what has just been said, the question might naturally arise, as cork is the bark of a tree, is it not subject to dry rot, as lumber would be. Replying to a similar question, Prof. J. M. Ordway, of the Massachusetts Institute of Technology, and later of Tulane University, once said: "Cork is no more wood than starch is wood. It is chemically and structurally different." This curious material is the bark of a species of oak (*Quercus Suber*), which grows more or less freely throughout southern Europe and northern Africa. According to De Candolle, a French writer whom Darwin quotes with approval in his "Origin of Species," the oaks of the world are derived from a common ancestor. This point of view permits a very interesting comparison between our northern red and white oak, which grow in cool, well-watered lands, and their

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southern cousin, the cork oak, living in a hot, dry climate. Everyone is familiar with the dense hard bark of the American oaks, perhaps one-quarter inch thick, and it is hard to realize that the soft, elastic covering of the cork oak, a covering two inches or more in thickness, on the tree, is only a modified form of the same thing; a beautiful illustration of Nature's care for her creatures, adapting their equipment to their need. "As their day is, so shall their strength be."

The cork oak grows in dry sandy soil swept by hot winds and sand storms; water is scarce and what the tree obtains would be evaporated before it reached the upper branches and leaves were it not for the special protection Nature has designed in the heavy cork bark. This answers the double purpose of keeping out the excessive heat and keeping in the life-giving moisture. It is Nature's answer when the question of insulation is put fairly up to her, and her last word is certainly impressive.

Cork, both granulated and in compressed blocks, is highly efficient in cold storage practice as a non-conductor of heat, free from capillary attraction and from any tendency to absorb moisture freely. These last are specially valuable qualities on account of their rarity, and have operated to give this material the high place it occupies among cold storage insulators, even more than its marked value as a heat retarder.

There is one more point to which attention should be called, for, though it has nothing to do with insulation directly, yet indirectly it is closely connected. This is the wisdom of coating thoroughly the exterior walls of cement or brick cold storage buildings with some effective waterproofing compound. This should be done when the walls have thoroughly dried out, and is of marked value if done then. The customary way is to damp-proof the inside surface, and let the external moisture soak in through the walls unhindered until it reaches this inner film. The insulation has hard work to do, and needs all the legitimate aid that can be given. A general who permitted the enemy to reach his inner line of defense before striking a blow would not take high rank as a strategist. In this case the enemy is fully as real and the outer wall is the place to make the first stand.

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No. 29.

HORSE POWER PER TON OF REFRIGERATION OF AMMONIA COMPRESSION MACHINES.

By Thomas Shipley, York, Pa.

(Member of the Society.)

The question of horse power per ton of refrigeration of compression machines is broad and indefinite, owing to the fact that no set of conditions has been laid down and adopted by the engineering fraternity as the standard conditions under which a ton of refrigeration shall be calculated.

Until such a standard is adopted no standard of power required per ton of refrigeration can be arrived at.

The best that can be done at present is to tabulate the power required to do the work of one ton of refrigeration, taking in the usual conditions under which refrigerating and ice-making machines are operated.

Then with the suction and condensing pressures given, together with the condition under which the compressor is to be operated, the capacity of the compressor and the horse power per ton can be determined with reasonable accuracy.

An idea of the range that such a table may take in can be had by reference to a table which has long been published in the catalogue of one of the manufacturers of this class of machinery.

The title of this table (Table I) is "Horse Power Required to Produce One Ton of Refrigeration."

It covers nine condensing pressures, ranging from 103 pounds to 218 pounds; also twelve low or evaporating pressures, ranging from 4 pounds to 51 pounds; and it gives 108 different amounts of power required per ton of refrigeration, ranging from .3 of a horse power per ton to 1.691 horse power per ton.

The table represents the minimum theoretical power utilized in a compressor to compress sufficient ammonia gas, which, when liquefied at the pressure stated, will, upon being evaporated from the temperature corresponding to said pressure, to the temperature corresponding to the pressure in the evaporating system, do the same amount of work as is done by the melting of one ton of ice.

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Table No. I.

HORSE POWER REQUIRED TO PRODUCE ONE TON OF REFRIGERATION.

Refrigerator Pressure and Temperature.		Condenser Pressure and Temperature.									
		P	103	115	127	139	153	168	184	200	218
P		T	65°	70°	75°	80°	85°	90°	95°	100°	105°
4		—20°	1.0584	1.1304	1.2051	1.2832	1.3611	1.4427	1.5251	1.6090	1.6910
6		—15°	.9972	1.0692	1.1450	1.2221	1.3001	1.4101	1.4609	1.5458	*1.7300
9		—10°	.9026	.9777	1.0458	1.1183	1.1926	1.2602	1.3471	1.4352	1.5093
13		—5°	.8184	.8833	.9537	1.0230	1.0935	1.1679	1.2437	1.3209	1.3964
16		0°	.7352	.8008	.8648	.9328	1.0019	1.0718	1.1467	1.2194	1.2547
20		5°	.6665	.7312	.7946	.8593	.9278	.9978	1.0656	1.1381	1.2121
24		10°	.5915	.6629	.7257	.7894	.8545	.9205	.9911	1.0595	1.1294
28		15°	.5410	.5998	.6641	.7276	.7924	.8553	.9234	.9943	1.0603
33		20°	.4745	.5340	.5923	.6716	.7148	.7796	.8420	.9031	.9736
39		25°	.4108	.4659	.5227	.5804	.5992	.7022	.7667	.8289	.8922
45		30°	.3509	.4056	.4612	.5178	.5755	.6353	.6944	.7590	.8172
51		35°	.3005	.3546	.4101	.4666	.5214	.5804	.6398	.7009	.7629

Note—The figures in this table represent the minimum theoretical amount. In practice they must be increased about 50 per cent.

Copied from the catalogue of the De La Vergne Machine Company.

* Evidently a mistake; should have been 1.63.

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When a specification calls for bids on a refrigerating machine of a stated capacity and asks for a guarantee of the horse power per ton of refrigeration and does not state the condition under which the work is to be performed, the table referred to shows that the salesman has a choice of at least 108 different conditions under which to figure his horse power per ton, and these conditions give him a range of 550 per cent. from the lowest to the highest, and if horse power per ton will influence the letting of the contract he is apt to make it low enough to attract attention.

This he has a perfect right to do under the specification and in the absence of a standard condition being adopted by the trade.

When the machine is erected and is started up the purchaser often finds it will not do the amount of work he expected it would, and upon complaining to the contractor he is promptly informed that he is not furnishing the conditions under which the machine was supposed to be operated, and he finds that he must either furnish the conditions called for by the contractor or accept the machine. In case the purchaser fails to furnish the conditions called for by the contractor the horse power per ton guarantee becomes a dead letter, and the purchaser has no redress.

To avoid this difficulty a specification should specify all the conditions under which the machine is to be operated.

The horse power per ton of refrigeration given in Table I is the minimum, and is based upon the assumption that the compressor is operating at 100 per cent. efficiency, that is, dry compression, without any loss from superheating, clearance or any other cause.

It is necessary to know the actual efficiency of a compressor before the horse power per ton can be calculated, and it is also necessary to have a knowledge of how much of the loss is due to clearance.

Indicator cards will show the loss from clearance, but they will not show the superheat or the efficiency of the compressor.

The following cards taken during a series of clearance tests will illustrate this fact:

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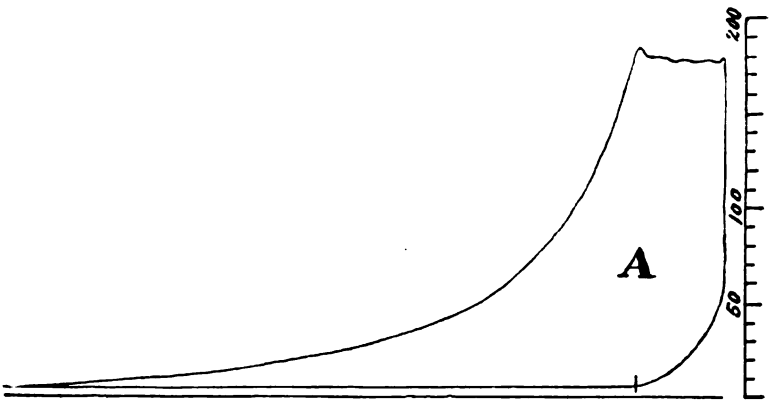
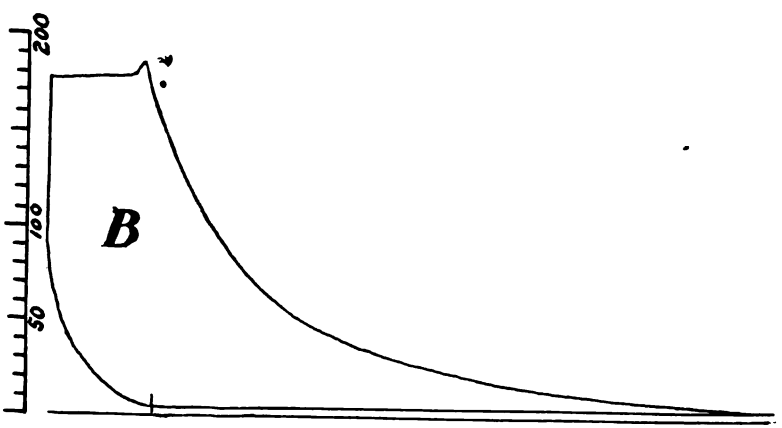
Run No. 470—2:15 P. M., November 5, 1906.

Scale, 100; 12″ × 18″ single acting compressors; ¼″ clearance = 1.39 per cent. of stroke; 1055.4 revolutions in 15 min.; back pressure, 5.2 lbs., gauge; condenser pressure, 185 lbs., gauge; actual volumetric efficiency, 68.78 per cent.



12.6 per cent. re-expansion loss; 13.5 per cent. for isothermal expansion.



14.3 per cent. re-expansion loss; 13.5 per cent. for isothermal expansion.

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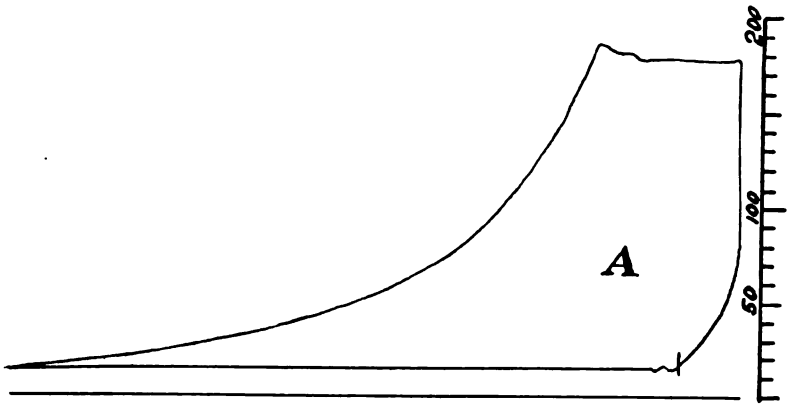
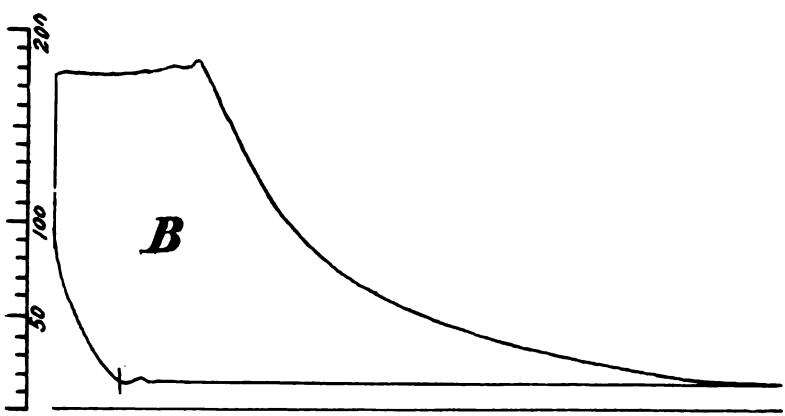
Run No. 464—2:15 P. M., October 31, 1906.

Scale, 100; 12½″ × 18″ single acting compressors; ¼″ clearance = 1.39 per cent. of stroke; 1036 revolutions in 15 min.; back pressure, 15.71 lbs., gauge; condenser pressure, 185 lbs., gauge; actual volumetric efficiency, 76.33 per cent.



8.8 per cent. re-expansion loss; 8.9 per cent. for isothermal expansion.



9.15 per cent. re-expansion loss; 8.9 per cent. for isothermal expansion.

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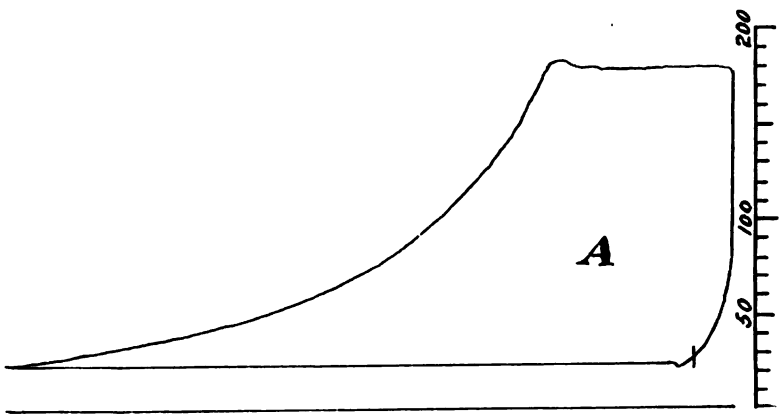
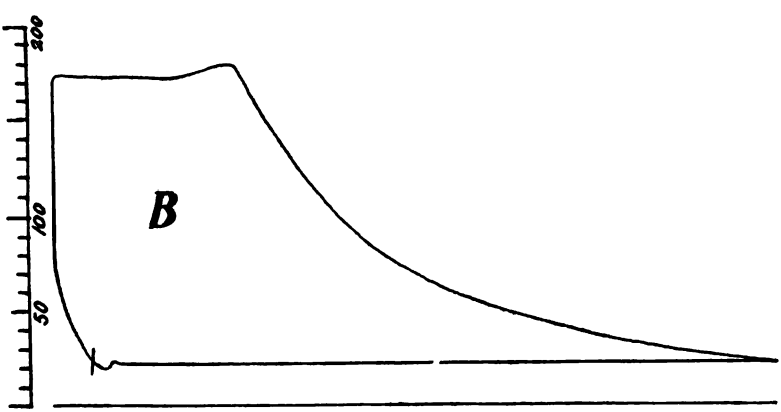
Run No. 476—5:00 P. M., November 8, 1906.

Scale, 100; 12½″ × 18″ single acting compressors; ¼″ clearance = 1.39 per cent. of stroke; 1050 revolutions in 15 min.; back pressure, 25.08 lbs., gauge; condenser pressure, 185 lbs., gauge; actual volumetric efficiency, 81.13 per cent.



5.5 per cent. re-expansion loss; 6.8 per cent. for isothermal expansion.



5.7 per cent. for re-expansion loss; 6.8 per cent. for isothermal expansion.

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These cards were taken from a vertical machine having two single-acting compressors, each 12½x18 inches, with one-quarter of an inch clearance between piston and discharge head, equaling 1.39 per cent. of the stroke, while the machine was being operated under dry compression condition.

The following is a comparison of the conditions as shown by the cards, and actual conditions as determined by the tests:

Run No. 470.—At 5.2 pounds, which was the suction pressure of this run, the theoretical loss from clearance would be 13.5 per cent. Indicator cards give 13.5 clearance loss. Indicator cards show 86.5 per cent. volumetric efficiency. Actual efficiency was 68.78 per cent.

Run No. 464.—At 15.71 pounds, which was the suction pressure of this run, the theoretical loss from clearance would be 8.9 per cent. Indicator cards give 8.72 per cent. clearance loss. Indicator cards give 91.28 per cent. volumetric efficiency. Actual efficiency was 76.38 per cent.

Run No. 476.—At 25.08 pounds, which was the suction pressure of this run, the theoretical loss from clearance would be 6.8 per cent. Indicator cards give 5.6 per cent. clearance loss. Indicator cards show 94.4 per cent. volumetric efficiency. Actual efficiency was 81.13 per cent.

The series of tests from which these cards were taken are being run principally to determine what effect clearance has on the horse power per ton of refrigeration, tests having been run on our single-acting machine, with $\frac{1}{32}$, ⅛, ¼, ½ and 1 inch clearance, each under 5 pounds, 15.67 pounds and 25 pounds suction pressure.

The tests on the double-acting machine, which is the same size as the single-acting machine and is driven by the same engine, are now being run.

I am unable to say how much clearance affects the horse power per ton, as the tests we are running are not finished, and when they are it will take considerable time to get the data into shape and compare them with other tests we have made along the same lines.

I will say, however, that clearance affects the displacement required per ton much more than it does the horse power per ton.

In connection with the statement that to know the amount of clearance it is necessary to be able to calculate the horse power per ton, I will say that superheat is a dead loss in horse power per ton, while clearance is not, and as they both go to make up efficiency it is necessary to have knowledge of the amount of each.

Superheat is always present when running dry compression, while clearance may or may not be.

The speed of the compressor affects the horse power more than is supposed, and, contrary to the opinions of most experts, the higher

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the speed up to the limit of the valves, say 100 revolutions per minute, the less will be the horse power per ton.

If a liquid cooler is used the effectiveness of each pound of liquid ammonia is increased, and this reduces the amount of gas to be handled per ton, thereby reducing the horse power per ton. A considerable saving can be effected by this means.

For instance, with a condensing pressure of 185 pounds the liquid ammonia leaves the condenser at about 95°. If this liquid is cooled at 65°, a saving of over 6½ per cent. can be made in both horse power and displacement per ton.

This means 6½ tons of ice on a 100-ton plant, or 3¼ tons on a 50-ton plant, which is no small item to the owner.

The difference in the horse power per ton of refrigeration, when a machine is run under a dry compression condition and when run under a wet compression condition, is shown in Table II, which shows the average results of six wet and six dry compression runs of about six hours each, on a 12½x18 inch double-acting horizontal ammonia compressor, direct connected to an 18x18 inch horizontal Corliss steam engine.

These tests were made to determine how many more revolutions per minute and how much more horse power per ton were required to do a given amount of work, running wet compression, than were necessary to do the same amount of work running dry compression.

The condensing and suction pressures and the work were constant. The revolutions and the horse power were the variables. The wet and dry runs alternated.

TABLE No. II.

DIFFERENCE IN HORSE POWER PER TON OF REFRIGERATION BETWEEN WET AND DRY COMPRESSION.

	Wet Compression.	Dry Compression.
Tonnage of refrigeration (brine cooling)	20.94	20.47
Total I. H. P. of compressor	42.88	32.83
Total I. H. P. of engine	49.51	36.16
Friction in per cent. engine horse power	13.31	8.73
Compressor I. H. P. per ton of refrigeration	2.066	1.603
Engine I. H. P. per ton of refrigeration	2.368	1.766

From the above it will be seen that running a machine wet compression means a considerable increase in horse power per ton over dry compression. It will also be noticed that the engine friction is very much larger with wet compression.

Table III is one I have had gotten up for the use of our

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Table No. III.

DISPLACEMENT AND HORSE POWER PER TON OF REFRIGERATION, YORK MANUFACTURING COMPANY'S SINGLE-ACTING AND DOUBLE-ACTING COMPRESSORS—DRY COMPRESSION.

Condenser Gauge Pressure and Corresponding Temperature = Temperature of Liquid at Expansion Valve.		Suction Gauge Pressure and Corresponding Temperatures.														
		5 lbs. = −17.5° F.			10 lbs. = −8.5° F.			15.67 lbs. = 0° F.			20 lbs. = 5.7° F.			25 lbs. = 11.5° F.		
		Volumetric Efficiency Per Cent. of Displacement.	Cubic In. Displacement Per Min. Per Ton of Refrigeration.	I. H. P. Per Ton (Compressor).	Volumetric Efficiency Per Cent. of Displacement.	Cubic In. Displacement Per Min. Per Ton of Refrigeration.	I. H. P. Per Ton (Compressor).	Volumetric Efficiency Per Cent. of Displacement.	Cubic In. Displacement Per Min. Per Ton of Refrigeration.	I. H. P. Per To (Compressor).	Volumetric Efficiency Per Cent. of Displacement.	Cubic In. Displacement Per Min. Per Ton of Refrigeration.	I. H. P. Per Ton (Compressor).	Volumetric Efficiency Per Cent. of Displacement.	Cubic In. Displacement Per Min. Per Ton of Refrigeration.	I. H. P. Per Ton (Compressor).
145 lbs. = 82° F.....	S. A.	79.	12608.	1.654	81.2	9811.	1.4	83.	7829.	1.195	84.2	6765.	1.065	85.5	5836.	.943
	D. A.	68.	14645.	1.921	70.5	11300.	1.612	73.	8901.	1.358	74.7	7625.	1.2	76.5	6522.	1.054
165 lbs. = 89° F.....	S. A.	77.5	13045.	1.834	79.7	10148.	1.56	81.5	8092.	1.341	82.7	6990.	1.201	84.	6027.	1.071
	D. A.	66.5	15203.	2.137	69.	11720.	1.802	71.5	9224.	1.529	73.2	7898.	1.357	75.	6751.	1.2
185 lbs. = 95.5° F...	S. A.	76.	13491.	2.013	78.2	10487.	1.72	80.	8362.	1.4865	81.2	7219.	1.336	82.5	6223.	1.197
	D. A.	65.	15774.	2.354	67.5	12150.	1.993	70.	9555.	1.7	71.7	8176	1.513	73.5	6985.	1.344
205 lbs. = 101.4° F..	S. A.	74.5	13947.	2.192	76.7	10834.	1.879	78.5	8630.	1.631	79.7	7450.	1.47	81.	6430.	1.323
	D. A.	63.5	16362.	2.571	66.	12590.	2.184	68.5	9890.	1.87	70.2	8459.	1.67	72.	7222.	1.488

Note—The above table represents efficiencies and displacements where the clearance does not exceed one-thirty-second of an inch.

Unless the clearance is excessive no addition to the horse power will be necessary.

Where liquid is cooled lower than temperature corresponding to condensing pressure, there will be a reduction in horse power and displacement proportional to the increase of work done by each pound of liquid handled.

For engine horse power add 17 per cent. to the compressor horse power up to 20 tons' capacity, and 15 per cent. for larger machines.

This table is based on tests made before January 1, 1906.

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engineers and salesmen. It is based on the tests the York Manufacturing Company ran with its test plant in York, Pa., up to January 1, 1906, and it gives the efficiency, displacement and compressor horse power per ton of refrigeration for both single-acting and double-acting machines for 145 pounds, 165 pounds, 185 pounds and 205 pounds condensing pressure, and for 5 pounds, 10 pounds, 15.67 pounds, 20 pounds and 25 pounds suction pressure, the machines working under dry compression conditions with not more than a working clearance of $\frac{1}{32}$ inch.

We have gotten somewhat better results in our tests than are shown by this table, but the figures given are safe for practical use.

When we work up all the data we have accumulated, it may be necessary to change some of these figures.

Our tests have shown us that the compression line on the cards runs closer to the adiabatic line than to the isothermal line, cutting the space between these two lines as 1 is to 2, whereas in general practice it is assumed to be midway between these curves.

The compression curve used in getting the mean effective pressures in Table I evidently runs slightly closer to the adiabatic curve, but very close to midway between the two curves.

I would call attention to the fact that the efficiencies given in Table III are based on the pressure in the suction pipe entering the compressor.

While Table I is based on the internal suction pressure, as shown by indicator cards, and since it is impossible to fill a compressor to exactly the pressure in the suction pipe, the proper pressure to base the efficiency upon is the pressure in the suction pipe, for upon this pressure depends the temperature in the evaporating system, where the useful work of refrigeration is done.

If the efficiency is not based on the pressure in the suction pipe, then the compressor, which draws its charge of gas through a small valve in the head, generally in a horizontal position, where it cannot be properly balanced, will be classed with the single-acting machine with its large, properly balanced suction valve placed vertically in the piston. Table III will illustrate this point.

The single-acting machine from which part of this data was obtained is of the single-acting vertical type, with a large balanced suction valve set vertically in its piston.

The double-acting machine from which the balance of the data was obtained is of the horizontal spherical head type, with the suction and discharge valves set on the horizontal in each head, the

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suction valve being as large as the head will allow, and as near balanced as is possible under this construction.

In my opinion the main reason for the difference in efficiency of these two machines is caused by the suction valves.

I further believe that the single-acting machines, having small suction valves in the head or on the barrel of the compressor, will not show better efficiencies than are shown by a double-acting machine; in other words, there is no use building a single-acting machine unless the suction valve is in the piston, where it can be properly balanced to allow of as near a full charge of ammonia as is possible to enter the compressor.

In attempting to calculate the horse power per ton of a machine running wet compression, Tables I and III can only be used to approximate the horse power per ton of refrigeration by using the comparison shown in Table II.

Indicator cards are of very little help in arriving at the horse power per ton of a wet compression machine, for they do not indicate the amount of ammonia the compressor is handling, nor can the amount required to be handled be determined in any other way than by experiment.

As to volumetric efficiencies, cards are of no use in connection with a machine operated under a wet compression condition.

The following cards will show the difference between cards taken from the same machine, running under wet condition and dry condition, the sets being taken about six hours apart during the tests where the data upon which Table II is based were obtained.

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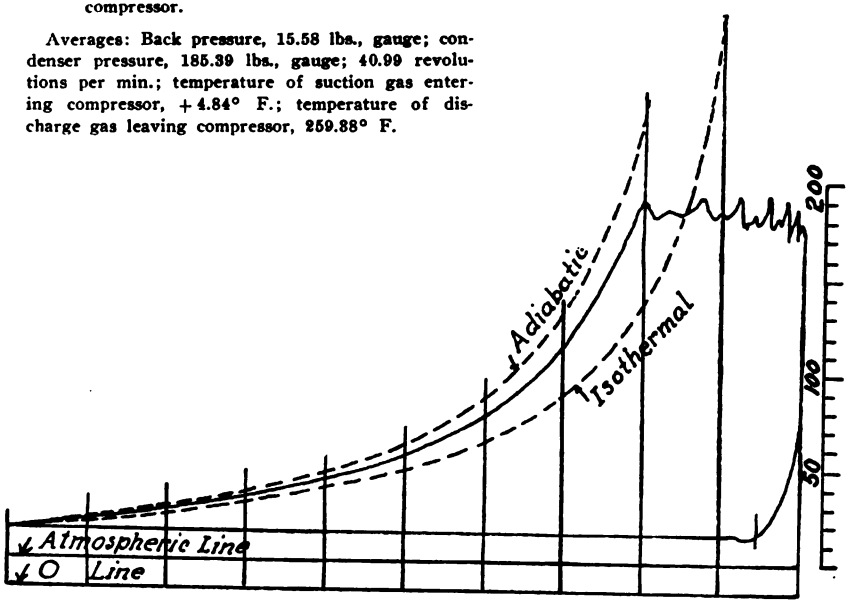
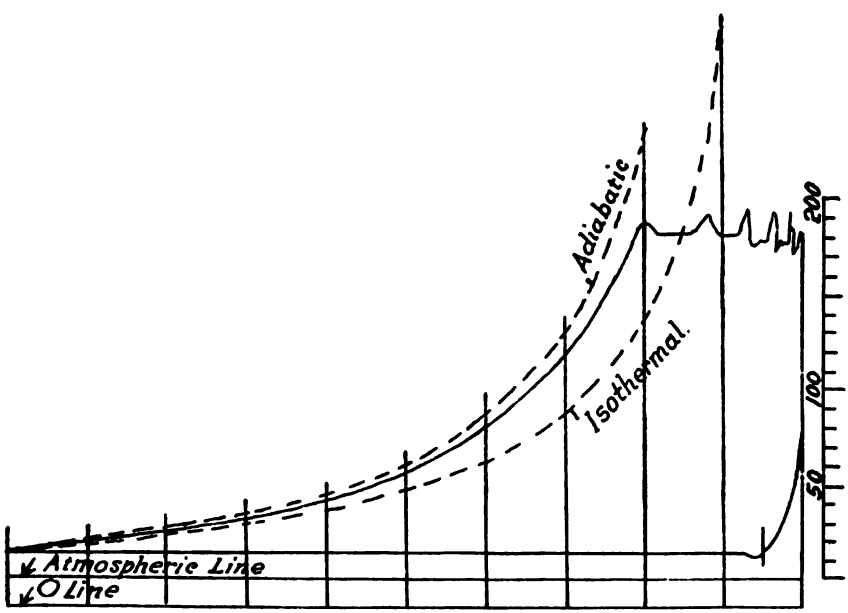
Run No. 399—Dry Compression—scale, 100; 12½″ × 18″ double acting compressor.

Averages: Back pressure, 15.58 lbs., gauge; condenser pressure, 185.39 lbs., gauge; 40.99 revolutions per min.; temperature of suction gas entering compressor, + 4.84° F.; temperature of discharge gas leaving compressor, 259.88° F.



Crank end—5.2 per cent. re-expansion loss.



Head end—5.2 per cent. re-expansion loss.

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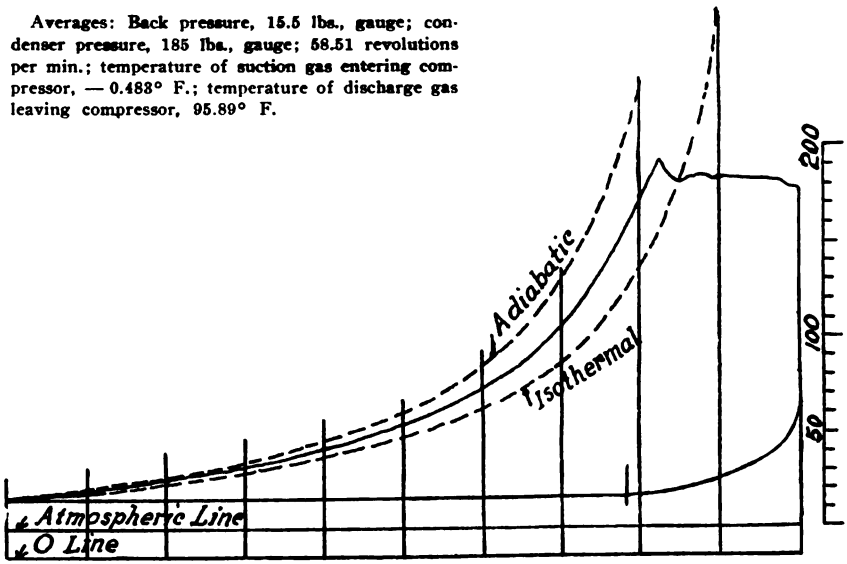
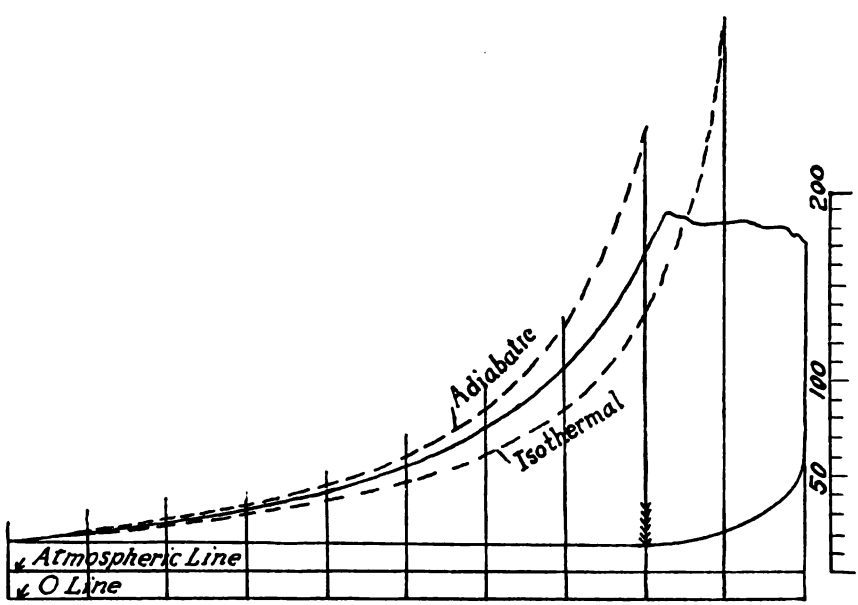
Run. No. 398—Wet Compression—Scale, 100; 12½" × 18" double acting compressor.

Averages: Back pressure, 15.5 lbs., gauge; condenser pressure, 185 lbs., gauge; 58.51 revolutions per min.; temperature of suction gas entering compressor, — 0.483° F.; temperature of discharge gas leaving compressor, 95.89° F.



Crank end—21.6 per cent. re-expansion loss.



Head end—19.9 per cent. re-expansion loss.

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Cards No. 399 are the dry compression cards, the actual volumetric efficiency of which was 73.1 per cent.

Cards No. 398 are the wet compression cards, the actual volumetric efficiency of which was 75.6 per cent.

It will be noticed that the compression line on the wet compression cards is about midway between the isothermal and adiabatic curves, and that the loss due to re-expansion is about four times as much as is shown by the dry compression cards.

Evidently the cause of the compression line swinging away from the isothermal curve is the gas formed by the vaporization of the liquid which kept the temperature down in the compressor.

The excessive re-expansion is due to the presence of liquid in the clearance space. The total loss from the vaporization on the suction stroke of the compressor is not shown by the cards. This loss must be considerable.

The clearance shown by the card does not account for all the loss, as indicated by the volumetric efficiency, even if we assume that nothing but gas was discharged at the end of each stroke. This, however, could not be the fact, because it would be impossible to vaporize in the compressor 11 pounds out of the 36 pounds of ammonia which passed through it per ton per hour, since it requires the same amount of ammonia to do a ton of work in the evaporating system, whether the machine is run wet or dry compression.

Inasmuch as the average amount of ammonia handled per ton of refrigeration per hour during the twelve tests referred to was, to be exact, 25.02 pounds for the dry compression runs and 35.98 pounds for the wet compression runs, then about 11 pounds of liquid ammonia must have been passed into the compressor to keep it cool, and a large percentage of it must have passed out into the discharge pipe as liquid, thereby decreasing the volumetric efficiency of the wet compression from that given above.

Under the dry condition it required an average of 43.92 revolutions per minute to handle the 25 pounds of ammonia gas necessary to produce one ton of refrigeration in the evaporating system, while under the wet condition it required 61.49 revolutions per minute to handle the same amount of gas, and this explains the difference in horse power per ton of refrigeration, for the useful work of the compressor is to handle the gas that has been formed doing work in the evaporating system.

In connection with these statements I want to say that the amount of liquid allowed to come over to the compressor in the tests referred to was the minimum amount that would keep the discharge

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temperature at the point required, and I can assure you that it requires much work and experience and very careful watching to keep the liquid down as low as given, and a hundred times more attention than is given to any commercial plant.

In conclusion I would urge the necessity of the adoption of standards in our business. It is certainly in a "free for all" state at present, not only as to the horse power per ton but as to every part that goes to make up a complete plant.

Every manufacturer, every expert and every owner has a standard of his own; to wit, his own likes and dislikes.

Some of the specifications that have come to my notice should be framed as monuments of either the ignorance or the dishonesty of the men who got them up.

We are standing in our own light if we do not do everything we can to advance the profession we have adopted, and every fact and item of data made public makes it harder for the "quack" expert, whether in the guise of manufacturer, salesman or consulting engineer, to fool a purchaser, and by doing so he not only robs his customer or client but injures and disgraces your profession and mine.

DISCUSSION.

Edgar Penney—How do you introduce the liquid ammonia in the wet compression machine? Do you simply let it flow through the pipes?

Thomas Shipley—That is the way we did finally. We also tried it with a spray injection pipe.

Edgar Penney—Have you any spraying arrangements?

Thomas Shipley—If you mean a nozzle, no.

Edgar Penney—Did you ever use a spray or anything to divide the ammonia in a spraylike form, to distribute it over the surface of the compressor?

Thomas Shipley—No. My first experience with compression refrigerating machines was with machines some of which used an injection in the compressors direct, and others used an injection into the suction pipe just as it entered the compressors. The nozzles were of no use, as the valve which regulated the amount of liquid ammonia used broke the ammonia into a spray, and the nozzle collected this mist and formed it into drops, thus doing harm instead of good. Hence we abandoned the use of nozzles, and in these experiments we did not waste any money on them. We tried intro-

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ducing the liquid ammonia necessary to cool the compressor by injecting it in the suction pipe as it entered the compressor, but we found it impossible to keep a constant back pressure, because it was made up of ammonia coming from two sources.

R. L. Shipman—Once during a test we tried a scheme where we put in a horizontal double-acting compressor with an expansion valve in both heads, which would give a very even distribution of the liquid in the cylinder. That showed no gains whatever. There has been practically no difficulty indicated by running the spray into the suction line.

Thomas Shipley—As Mr. Shipman has just remarked, we tried injecting the liquid into each end of the double-acting machine, with the results he has stated. Our experience showed that it was possible to get better results and more even operation by allowing the ammonia to come over from the evaporating coils, carrying sufficient liquid to cool the compressor, than by injecting it as I have explained. It also gave us the exact conditions under which the commercial wet compression plant is operated. What we tried to do was to determine the difference between operating a compressor under wet conditions and under dry conditions, using the same apparatus and doing exactly the same amount of work, making the difference show up in the revolutions of the machine, so that it would not take an expert to see the difference. We conducted our tests in this way: We alternated the conditions, first wet, then dry, again wet and again dry, and so on, continuing the tests for several weeks, to get reliable averages. The results are given in the tables presented in my paper.

Edgar Penney—Did you make any experiments with regard to the position of the valves?

Thomas Shipley—Yes; we turned the valves on one end of the compressor in line with the vertical axis, leaving those at the other end on the horizontal axis during a number of our tests, but could not detect any difference in the efficiency of either end of the compressor, nor of the compressor as a whole.

Gardner T. Voorhees—I was interested in the chart. Under that one chart that Mr. Shipman spoke of, I think he said that the wet compressor gave approximately 15 per cent. of the horse power and the dry 8 per cent. In the third line from the bottom it is about 9 per cent—that is, friction in per cent. of the engine horse power?

Thomas Shipley—Yes.

Gardner T. Voorhees—It looks to me as if that was extraor-

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dinarily low friction, as low as the friction of an engine without any compressor attached. I have in mind the eight very splendid tests made by Professor Denton some years ago, on, I think, a 10 by 30 inch Consolidated machine. It had two single-acting compressors and a vertical engine, and the average friction loss of those eight tests, working from 8 pounds gauge back pressure to 28 pounds gauge back pressure, as I recall it, was 22 per cent. of the engine horse power. Taking those eight tests, which were carefully made, and seeing the friction used per horse power, running up to 22 per cent., what you claim as a test seems inconceivable, and I would like to have this explained. I would like to know if it were the result of one test or the results of a number? If you assume that the dry compressor can be operated at less than 10 per cent. friction loss, is it the result of an extended series of tests?

Thomas Shipley—You want to know how we made up those tests?

Gardner T. Voorhees—No; whether that was a certain test under low conditions.

Thomas Shipley—The conditions are stated.

Gardner T. Voorhees—What was the back pressure?

Thomas Shipley—15.67 pounds gauge.

Gardner T. Voorhees—What was the condensing pressure?

Thomas Shipley—One hundred and eighty-five pounds gauge. The reason that the friction is so low is that the compressor is hung tandem behind the steam cylinder.

Gardner T. Voorhees—Is it your regular type of compressor that you put on the market?

Thomas Shipley—No.

Gardner T. Voorhees—That is what I am driving at.

Thomas Shipley—The comparison would be the same, would it not?

Gardner T. Voorhees—That is what I want to know, whether it was your regular type or a special machine?

Thomas Shipley—The machine is special, but the relative friction between the two conditions is represented by the figures shown. I am not trying to sell ice machines to any of you; I am only showing you what happened in our test. We are not trying to fool you.

Gardner T. Voorhees—I hope you do not think that I am trying to find fault with your splendid paper. The data are very fine;

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but what I want to know is what is the friction under ordinary conditions of the York machine.

Thomas Shipley—I am not trying to demonstrate anything about the York machine. This particular machine is not on the market.

Gardner T. Voorhees—Do you claim that you can operate the York machine with less than 9 per cent. friction or not?

Thomas Shipley—I am giving you a whole array of figures to tell you what we have done.

Gardner T. Voorhees—You are more familiar with those figures than I am. Taking ice-making conditions with 18 pounds back pressure and 175 pounds condensing pressure, what is the friction of the York machine?

Thomas Shipley—About 15 per cent. The machine used in these tests was one of our standard vertical single-acting machines, having a double-acting compressor of the same size as the single-acting compressor connected tandem to the horizontal Corliss cylinder of the vertical machine by extending the steam piston rod through the back head of the steam cylinder, and connecting it with the ammonia piston rod by a nut, the double-acting compressor being connected to the steam cylinder by a housing. In this way a comparison could be made between the single-acting and double-acting compressors without resorting to any corrections, they both being operated by the same engine, crank shaft, flywheel, etc., which would not be the case if they were separate machines.

When we wanted to run the single-acting compressors we disconnected the nut on the back extension of the steam piston rod where it took hold of the double-acting piston rod, and when we wanted to run the double-acting compressor we took down the connecting rods which operated the single-acting compressors, and connected up the piston rod of the steam cylinder to the piston rod of the double-acting compressor. In this way I believe we got an exact comparison between the horse power required to operate a single-acting machine and that required to operate a double-acting machine.

L. Williams—You have the shaft running?

Thomas Shipley—Yes; through the flywheel.

L. Williams—There would not be a great deal of friction?

Thomas Shipley—Not a great deal, but there would be a difference between 8 7-10 and about 15 per cent.

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L. Williams—I think you could reasonably expect better than 15 per cent. under those conditions.

Thomas Shipley—Yes; that is what we expect.

L. Williams—Did you measure the friction in each of those trials?

Thomas Shipley—Yes; it is averaged up for the six trials in each case.

L. Williams—On the wet compression cards the temperature of the discharged gas is shown as 95.89; have you got the temperature of the water in connection with the condensers on that trial?

Thomas Shipley—We kept all such data in our log. We used a double-pipe condenser.

L. Williams—Have you got the temperature of the water leaving the condenser? What I want to get at is some idea of the relation between the discharged gas and the temperature of the water leaving the condenser.

Thomas Shipley—I do not remember the temperature of the water leaving the condenser.

L. Williams—I understand that you leave the temperature of the ammonia as near as you can get it to the saturated temperature of 185 pounds of ammonia gas. What I want is some idea of the difference between the temperature of the water and the ammonia. We regulate our machines aboard ship at a difference of about 15°. That shows whether the machine is fully charged in our particular work with a submerged condenser.

Thomas Shipley—Yes.

L. Williams—I think that is used by the Linde Company on the other side.

Thomas Shipley—I have not got that in this table, but we aim to keep the high pressure constant; consequently, we would have to vary the amount of water used.

L. Williams—I do not understand what the temperature was between the water and the ammonia.

Thomas Shipley—We have got that in our data, but we have not tabulated it as yet.

Carl W. Vollmann—Mr. Shipley's paper is of great value, not to one side, but to all who are building machinery. The old question, which was taken up years and years ago, is to decide which system is the better, wet compression or dry compression. Now those who lean toward the dry system claim that theirs is the better;

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the others who are building machinery on the wet system make the same claim for their system. I do not remember now, but I think that twenty or twenty-five years ago tests were made on somewhat the same lines. The advocates of the wet system built a machine on their own principles, and the advocates of the dry system put a plant up after their ideas. The two were tested, and it was found, as far as I remember, that there was little difference between the wet and dry systems. I am, as perhaps you all know, in favor of the wet system, although I often adopt the dry system. As to the wet system, I have often found in my long practice that engineers who attend to machines of this type run the machines too wet; in other words, too cold. To get the best effect out of a wet system machine, it has to be so regulated that the delivery sides are kept warm. What we claim is that with the wet system the engineer is able to regulate the machine in such a way that by placing his hands on the delivery side he can decide at once whether the machine is doing its right work or not.

Mr. Shipley says that on the test the wet system might produce more than the dry system. If too much liquid ammonia passes through the system, then, as Mr. Shipley rightly says, the system cannot evaporate the ammonia, and the liquid is taken back to the compressor, with the result that the back pressure is kept too high in the system. In other words, the difference in temperature between the ammonia in the suction side and the brine is too small, and consequently the efficiency falls down, although the machine circulates the ammonia. This explains perhaps the discrepancy, why the difference between those two results is so large. As already stated, we claim that with the wet machine the engineer at any time may know if it is doing its work by placing his hand on the discharge side. If the discharge side is kept warm, then the ammonia which has passed through the system has evaporated and only just sufficient wet vapors are delivered back to the compressor to keep down overheating.

But, as stated before, Mr. Shipley has read a splendid paper and a paper like that requires very careful study, which could not be given in the few minutes that we devoted to listening to the paper. If we find that the dry system is the better, naturally we all will be only too glad to adopt it, or if the wet system is the better we should adopt that, or if we find that they are equal, let everyone use what he thinks best.

Thomas Shipley—I will try to answer Mr. Vollmann in regard to the difference between running a machine under wet condition

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and under dry condition, by saying that I believe it is impossible for a set of comparative tests to be made between the two conditions referred to and not discover the difference, because it is so great, unless those tests were made at a very high back pressure, for at a high back pressure the difference is not so great.

I do not remember having ever come across a record of the tests Mr. Vollmann refers to. I am of the opinion that if comparative tests were ever made, no attention was paid to the efficiency of the evaporating coils.

In testing out the several effects that running under a wet condition produced we found, among other things, that the evaporating coils were more than doubly as efficient operating under the wet condition as they were when operating under the dry condition. This fact shows why a machine running under a wet condition, and having only sufficient evaporating coils to do the work the machine is capable of under these conditions, cannot do the same amount of work if its mode of operation is changed to the dry condition, unless more than double the amount of the evaporating coils is used.

This fact is what, in my judgment, has given rise to the claims that the builders of wet compression plants make, and the fact that the wet compression plant is the cheaper to build has kept that plant on the market.

As soon as I found that a machine was so much more efficient under the dry condition and that the evaporating coils were so much more efficient under the wet condition, I set about to find the missing link necessary to run each of these parts of a plant under its most efficient condition.

This missing link we have found in our "flooded system." We have all parts of the plant operating under their best conditions.

Moreover, we can take a plant operating under wet conditions, and, by rearranging the connections to and from the evaporating system and adding a small additional apparatus, convert it into a "flooded system," and the machine will take care of nearly one-half more work with the same revolutions.

The sentiment that Mr. Vollmann expresses, namely, "let us find the best method or system and then adopt it," is the sentiment I have been trying to bring out, not only by advocacy but by practice.

Let us be honest to ourselves and honest to the people with whom we deal. We have been living on "hot air" long enough. It is time we got down to something better and more modern than the

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tests made twenty and twenty-five years ago, when this profession was in its infancy. Everyone will admit that the plants of to-day are not the same as those of twenty-five years ago. Then why should we be willing to base our practice on that established by tests made on inferior plants?

Let us get together and make tests and establish a practice that will be worth something, and have, at least, a decent foundation. Give a customer a chance to know what to expect when he asks for a certain size machine. Let us all bid on the same conditions of operation.

The York Manufacturing Company spent quite a large sum of money finding out these things. We have made nearly 500 tests during the past four years, and we are giving out the data obtained on these tests as fast as we can get them in proper shape.

We have shown you that we are willing to give you all the benefit of what we have learned and place it before you that you may pick it to pieces.

All we ask is that you do the same as we are doing: come out in the open and discuss the data you have. That is the only way to make them valuable.

The time has come when something more than looking wise is demanded of us, and such tables and information as I have presented to you, if not refuted and offset by other and better data, must stand as authentic before the profession, and the "hot air artist" must go down and out.

Henry Torrance, Jr.—We heard yesterday a great deal about a multiple-effect compressor, and if it is what it is represented to be, why should it not be tested? We have been discussing theories on it.

Gardner T. Voorhees—As to Mr. Torrance's suggestion, I will only be too glad if Mr. Shipley with his facilities would some time, when he is not too busy, rig up a machine and test for the multiple-effect result, and if there is any information that I can give him as to how to build or operate it I will co-operate with him in any way possible; that is, it would give me a great deal of pleasure if he would attempt to disapprove my statements.

Thomas Shipley—I think our test plant will be dismantled within a month. It is costing a great deal of money, and we are in need of room as well as the money that we have been spending, and I think we have got data enough to keep us two years figuring,

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and I think it is pretty near time to call a halt, so I shall not be able to accommodate Mr. Voorhees with a test of his multiple-effect machine.

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No. 30.

COOLING TOWERS.

By B. Franklin Hart, Jr., New York, N. Y.

(Associate Member of the Society.)

The cooling tower is the agent furnishing the necessary link needed to operate a plant where cool circulating water is necessary in order to obtain efficiency, and where a natural water supply is either lacking entirely or is of such a character that its use is attended with damage to pumps, condensers, etc.

The question of water supply in a refrigeration or ice plant is one of the problems which confront the manufacturer when considering ways and means. As a sufficient quantity of cooling water for steam or ammonia condensers is an absolute necessity, he must either locate on the water front, get his water from a well or buy it from the city.

The first condition is almost prohibitive in large cities, owing to the high cost of water-front property.

Again, the cost of driving a well, with the chance of not securing sufficient water, and also that the water might be of such a character that its use would clog up all passages, makes this a doubtful project, and finally the item of cost if water must be purchased from the city becomes a very large one.

In view of the above phases of the water problem, the cooling tower becomes a positive necessity in most cases, since the factory or plant may be placed with a single eye to central location as regards delivery and cost of land.

The cooling tower makes a plant practically independent of a water supply, and makes the water consumption simply the amount lost by evaporation.

In a plant already in operation, using circulating water drawn from extremely muddy streams carrying grit and sand that continually cut out pump pistons and cylinders, and which are also liable to freeze in the winter, the cooling tower becomes a crying need, since after several trips through the system the water becomes entirely free from impurities of this kind, and the small "make-up" necessary does not add enough to be considered. This is equally true in cases where there is trouble due to deposits formed in the pumps,

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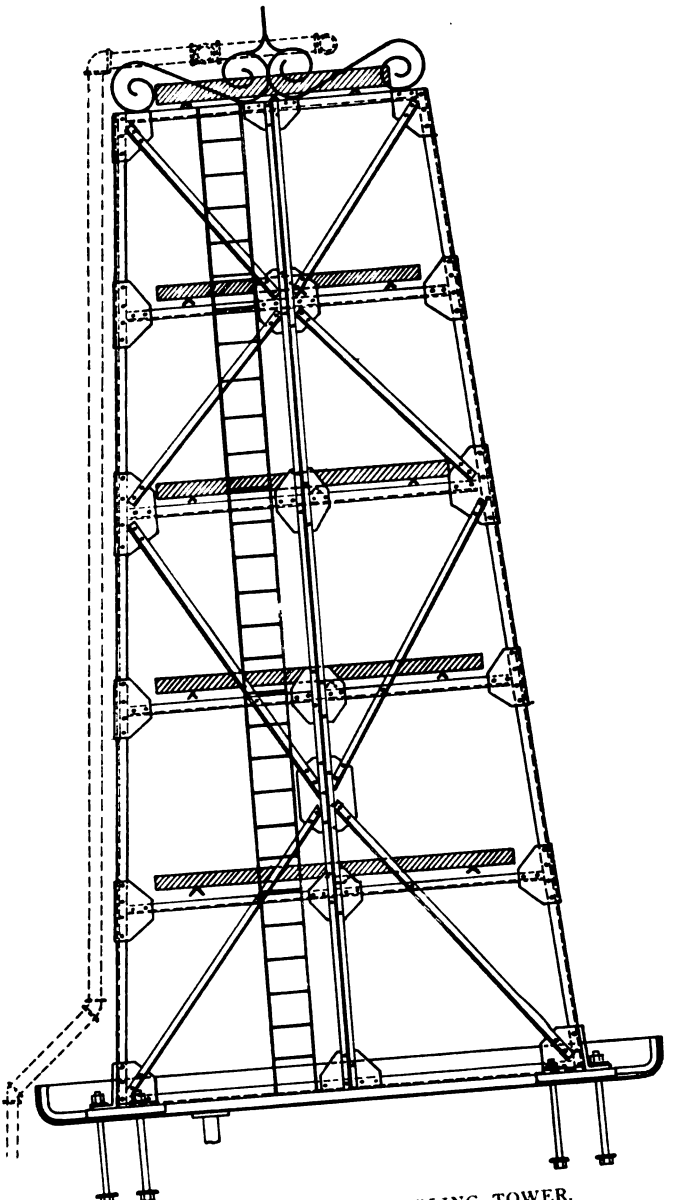

END ELEVATION—ACME COOLING TOWER.

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piping and condensers by well water containing excessive quantities of carbonates of lime and magnesia. Plants located where water systems are available simply buy the small "make-up" necessary at meter rates, and are independent of any other supply.

The principle upon which the cooling tower operates is simply the spreading of the circulating water in the way best calculated to bring the greatest surface in contact with the greatest quantity of air, so that evaporation may take place quickly and effectively. In actual operation the water coming from the condenser in a heated condition, when exposed to the cooler air surrounding it, is enveloped in a coating of vapor which is carried away by the air currents, and which is continually replaced and carried away by successive contacts with fresh quantities of air. Each cubic foot of atmospheric air has a vapor-carrying capacity which is governed principally by the percentage of moisture already in it, or, as it is called, its relative humidity. When the air is dry, or comparatively so, its heat-absorbing efficiency, measured by its vapor-carrying capacity, is high, as compared with a similar quantity of air at or near the point of saturation.

In other words, the cooling tower does its best work when the surrounding air is dry. The main point, then, in the design of a cooling tower is to distribute the water so that the greatest amount of surface is exposed.

In design, cooling tower construction is carried out with two ideas—natural draught and forced draught or fan towers.

Most of the early towers were designed to operate with fans, owing to the notion that the induced air currents would be more effective by the rapidity of their passage and the consequent volume of same; but this idea is fast giving place in most cases to the knowledge that it is not so much the volume of air coming in contact with the water to be cooled as it is the vapor-carrying capacity of the air.

It is for this reason that the open or fanless tower is coming into favor. It has been proven from many cases, and the data given below will also bear witness to the fact, that fan towers are unnecessary, and are really not as efficient as the open tower, except for installations where the tower must be placed in a location where there is no natural draught available.

In construction, cooling towers differ only in the method of distributing the water, the idea being to produce a tower that will give the greatest quantity of water surface in contact with the greatest quantity of air, and to do this with an apparatus that is simple, compact and ornamental, so that it really adds to the appearance of

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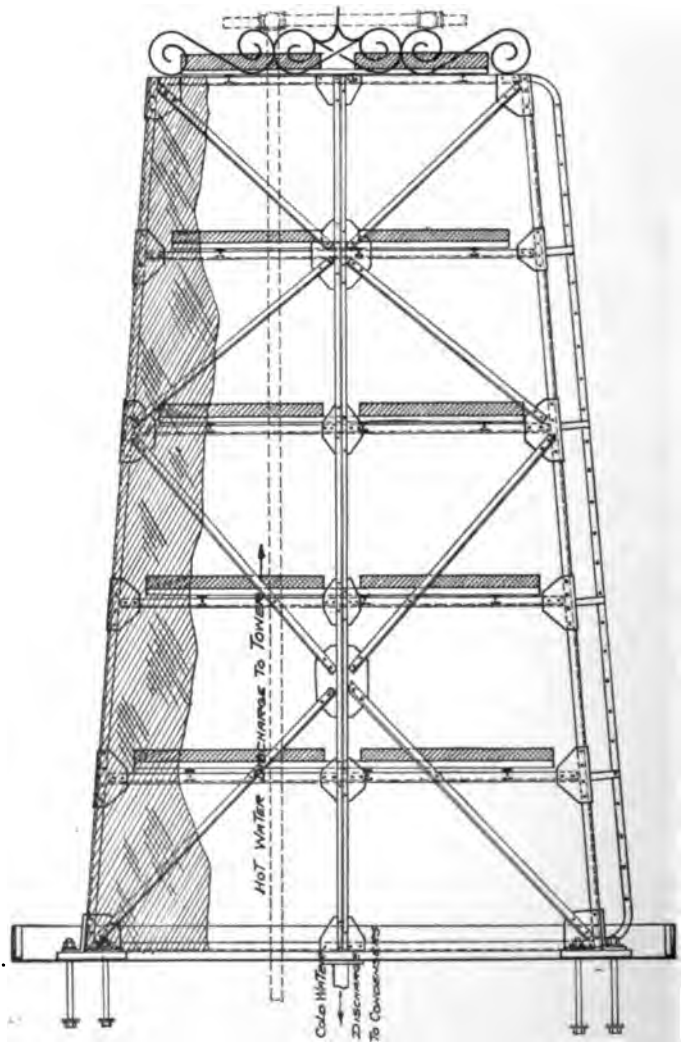

SIDE ELEVATION—ACME COOLING TOWER.

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a building rather than detracts when located on a roof at a prominent point.

The advocates of fan towers would say that with a fan they will be able to bring more air in contact with the water than would be the case in an open tower, except when the wind blows hard. There is an element not taken into account, however, which will explain why the open tower is really more efficient in this respect. The air being drawn into the bottom of a closed tower by the fans has a certain vapor-carrying capacity, which is gauged by its relative humidity. In other words, when the air is saturated with vapor it is no longer of use as a cooling agent, so that when air carrying a high percentage of humidity enters the bottom of a fan tower it almost immediately takes up all the additional vapor it can carry, and during the rest of the trip through the tower it is of no value whatever: whereas in the open tower the same quantity of air comes in contact with the water at the top of the tower, at the middle of the tower and at the bottom of the tower, and its efficiency is the same throughout the entire tower.

The readings shown herewith were taken at the Arnholt & Schaefer Brewing Company's plant, Thirty-first and Thompson streets, Philadelphia, Pa., from an "Acme" self-cooling tower, measuring 14x18 by 35 feet high. Views of the tower are shown herewith. There are five decks of spraying pans placed 7 feet apart, the pan surface on the top deck being 77 square feet. The tower was designed to cool 250 gallons of water per minute, the guarantee being to reduce the water to 80° F. when the temperature of the atmosphere did not exceed 80° F. nor the relative humidity 80 per cent.

These readings show observations taken daily, and covering the months of July, August, September and half of October, and show that this tower was doing excellent work.

The tower is placed on an exposed corner of the building, directly over the ammonia condensers. The water is caught by a concrete collecting pan lined with asphalt. The discharge water from the condensers drops to a 3-inch American Well Works belt-driven centrifugal pump, the pump discharging to the top of the tower, a point 65 feet above. The horse power necessary to run this pump is 7.8. The cooling tower, therefore, is doing its work. A glance at the results will show that the average temperature of the water leaving the tower throughout the month of July was 79.1° F., during August it was 79.4°, and during September it was 68.7°, so that this plant produced an ample quantity of cold water throughout

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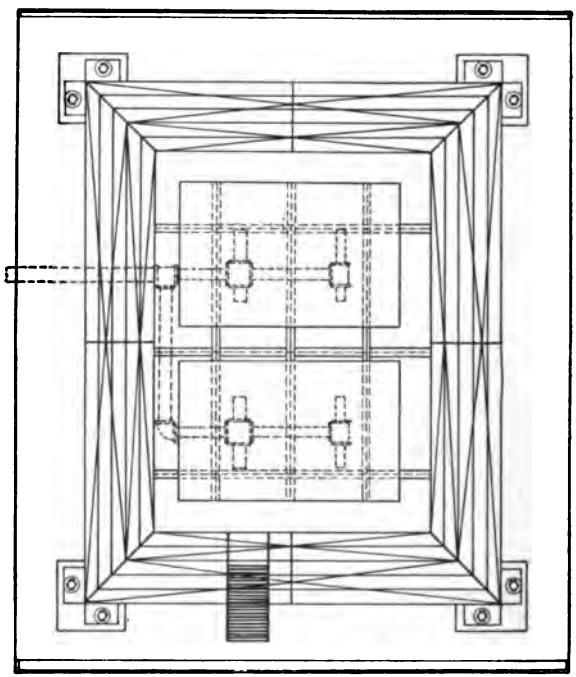

PLAN VIEW—ACME COOLING TOWER.

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the heated season without the use of fans, and with the total expense of operation of 7.8 horse power for driving the centrifugal pump. The pump in this case was placed far below the condenser, for the reason that an engine was available at that point to drive it.

EXTRACT FROM LOG OF "ACME" COOLING TOWER AT THE PLANT OF THE ARNHOLT & SCHAEFER BREWING COMPANY, PHILADELPHIA, PA.

1906.		Atmosphere.			Water.			Reduction in Temperature as Compared With Atmosphere.	
Date.	Time.	Wet Bulb. Deg.	Dry Bulb. Deg.	Hum. Rel. Per Ct.	Entering Tower. Deg.	Leaving Tower. Deg.	Reduction in Tower. Deg.	Degs. Below.	Degs. Above.
July 16,	3 P. M.....	84	75	60	88	82	6	2	..
" 16,	6 P. M.....	79	76	85	90	83	7	4	..
" 17,	8 A. M.....	82	75	68	93	84	9	..	2
" 18,	4 P. M.....	92	72	34	90	77	13	15	..
" 19,	10 A. M.....	82	72	57	90	80	10	2	..
" 20,	4 P. M.....	94	77	41	90	82	8	12	..
" 21,	11 A. M.....	87	75	52	90	81	9	6	..
" 22,	1 P, M.....	91	75	42	89	81	8	10	..
" 23,	10 A. M.....	84	75	60	84	78	6	6	..
" 24,	8 A. M.....	73	67	70	82	72	10	1	..
" 25,	1 P. M.....	80	67	47	79	71	8	9	..
" 26,	1 P. M.....	79	67	50	82	74	8	5	..
" 27,	8 A. M.....	70	66	78	83	77	6	..	7
" 28,	11 A. M.....	80	71	59	94	85	9	..	5
" 28,	1 P. M.....	86	72	46	87	79	8	7	..
" 29,	1 P. M.....	84	74	57	86	78	8	6	..
" 30,	11 A. M.....	84	76	64	86	70	7	5	..
" 31,	11 A. M.....	82	72	57	88	81	7	1	..
Mean results for month.		82.4	72.4	57	87.3	79.1	8.2	4.3	..
Aug. 1,	7 A. M.....	79	72	67	86	79	7	..	..
" 4,	4 P. M.....	92	78	47	88	82	6	10	..
" 5,	11 A. M.....	88	78	58	93	86	7	2	..
" 6,	11 A. M.....	89	77	52	88	84	4	5	..
" 6,	2 P. M.....	94	76	39	88	82	6	12	..
" 7,	8 A. M.....	80	74	71	92	84	8	..	4
" 8,	1 P. M.....	83	75	64	89	82	7	1	..
" 9,	1 P. M.....	84	71	48	84	77	7	7	..
" 10,	1 P. M.....	82	73	60	86	80	6	2	..
" 11,	2 P. M.....	90	78	53	89	83	6	7	..
" 12,	10 A. M.....	84	74	57	84	79	5	5	..
" 13,	1 P. M.....	74	66	62	76	72	4	2	..
" 14,	1 P. M.....	85	69	40	85	76	9	9	..
" 15,	1 P. M.....	82	61	30	84	76	8	6	..
" 18,	1 P. M.....	80	74	71	84	78	8	2	..
" 19,	1 P. M.....	84	74	57	88	81	7	3	..
' 20,	2 P. M.....	85	76	61	89	81	8	4	..
" 21,	1 P. M.....	88	77	55	93	84	9	4	..
" 22,	1 P. M.....	86	77	61	89	82	7	4	..
" 23,	1 P. M.....	84	79	76	92	83	9	1	..
" 24,	9 A. M.....	74	70	79	82	74	8	..	..
" 25,	1 P. M.....	68	66	88	76	70	6	..	2
" 26,	1 P. M.....	82	78	80	84	78	6	4	..
" 27,	1 P. M.....	84	77	76	89	82	7	2	..

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1906.		Atmosphere.			Water.			Reduction in Temperature as Compared With Atmosphere.	
Date.	Time.	Wet Bulb. Deg.	Dry Bulb. Deg.	Rel. Hum. Per Ct.	Entering Tower. Deg.	Leaving Tower. Deg.	Reduction in Tower. Deg.	Degs. Below.	Degs. Above.
Aug. 28,	1 P. M.....	77	68	59	81	73	8	4	..
" 29,	11 A. M.....	75	69	70	83	76	7	..	1
" 30,	2 P. M.....	87	77	58	91	82	9	5	..
Mean results for month.		82.9	73.4	60.9	86.4	79.4	6.9	3.3	..
Sept. 1,	6 P. M.....	78	60	35	82	77	5	1	..
" 2,	1 P. M.....	76	67	59	75	69	6	7	..
" 3,	2 P. M.....	85	72	49	77	71	6	14	..
" 4,	2 P. M.....	73	58	40	69	60	9	13	..
" 5,	1 P. M.....	78	67	53	66	62	4	6	..
" 6,	1 P. M.....	82	70	51	77	71	6	11	..
" 23,	1 P. M.....	80	67	47	80	71	9	9	..
" 24,	1 P. M.....	69	55	45	70	63	7	6	..
" 25,	1 P. M.....	70	57	45	73	65	8	5	..
" 26,	1 P. M.....	74	65	58	79	71	8	3	..
" 27,	1 P. M.....	76	70	71	83	76	7	..	..
" 28,	1 P. M.....	75	63	49	74	68	6	7	..
" 29,	1 P. M.....	78	70	63	82	74	8	4	..
" 30,	3 P. M.....	68	60	60	71	65	6	3	..
Mean results for month.		75.8	64.3	51.7	75.5	68.7	6.7	6.3	..
Oct. 1,	1 P. M.....	60	54	66	64	58	6	2	..
" 2,	1 P. M.....	70	61	57	72	66	6	4	..
" 3,	1 P. M.....	72	62	54	74	67	7	5	..
" 4,	1 P. M.....	64	63	94	73	68	5	..	6
" 5,	1 P. M.....	72	65	65	82	72	10	..	..
" 6,	1 P. M.....	70	67	83	82	74	8	..	4

DISCUSSION.

Edgar Penney—May I ask the capacity per hour of the tower you mention?

B. Franklin Hart, Jr.—Two hundred and fifty gallons per minute.

Edgar Penney—What was the number of pounds or gallons of water you lost through evaporation, etc.?

B. Franklin Hart, Jr.—We have no way of measuring that, because we had no meters. They are expensive things to put in. We know that the only water lost was from evaporation, and such as might sometimes be blown off the tower in the form of a spray.

Edgar Penney—You do not know how much water you handled?

B. Franklin Hart, Jr.—We know from our pump figures that we were handling from 200 to 250 gallons per minute.

Albert A. Cary—What form of hygrometer was used in these tests?

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B. Franklin Hart, Jr.—Wet and dry bulb hygrometer. We made the calculation from the table.

Albert A. Cary—Were the wet and dry bulbs placed against the walls of the building?

B. Franklin Hart, Jr.—The readings were taken right in the condenser room, where it was all open. The condensers were placed on what had formerly been the roof of the building, but the walls had been carried up for an extension and the tower was placed over it, and the roof was open except for the tower, and the hygrometer was placed so it was handy for the engineer.

Albert A. Cary—In asking this question I had the fact in view that the performance of a water tower depends largely upon the degree of atmospheric humidity. This is a very important matter, and in obtaining data concerning cooling tower efficiencies, especially if such information is collected for future reference, it is necessary for us to obtain the true humidity of the air. The ordinary hygrometer screwed against the wall, with no disturbance of the air surrounding it, does not give the true readings. The Weather Bureau of the United States Government found this to be a fact. The officials now use an instrument which they call a psychrometer. It is constructed with a wet and dry bulb screwed upon a board and made to revolve rapidly so that the dead air which ordinarily collects around the stationary bulb of a suspended thermometer is avoided. In observing the stationary hygrometer placed against the wall readings more nearly correct will be obtained by fanning the bulbs of the thermometers until your reading becomes stationary. You will find that this will change the reading of your wet bulb thermometer. If the hygrometer can be placed in the air current from an electric fan you get still better and truer results. This information is too important in the study of cooling towers to neglect such precautions, and I hope that in future cooling tower tests we will have hygrometer readings presented.

B. Franklin Hart, Jr.—As Mr. Cary says, the relative humidity is the key to the whole situation, and the brewery people were as careful as they could be in ordinary practice. It was simply a commercial hygrometer which was used, and it was placed so that it was in the draught.

John E. Starr—Another experience with the water tower is in regard to the precipitation of solids; theoretically, at least, the efficiency of the tower depends on evaporation. The water so evaporated does not carry with it any of the solids that may have been in suspension in the water. Hence, the expectation would be that,

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in time, with additions of water, the water being cooled would become rich in solids in solution. It would seem that the solids could not get away by evaporation, and hence they must either remain in the water or be deposited in the piping of the apparatus. I suppose that on an open condenser this feature may not be a very bad one, but in the inclosed type of condenser, or perhaps in spiral piping, it might be worse, and I would like to know whether Mr. Hart has any data on this subject, or whether any of the other members have noted any bad effects in this direction.

B. Franklin Hart, Jr.—Of course, as Mr. Starr says, some precipitation will occur where the water is bad. I have come in contact with cases where the water used was very heavily laden with carbonates of lime and magnesia, so much so that when that water solely was used as a cooling medium the precipitation was so great that in a few months it filled up all the outlets and passages and even the sewers, so that the city officials complained. A cooling tower was put in and city water used for the steam condenser, while the well water was used for the ammonia condenser. Where well water is used for the "make-up" water lost by evaporation, the precipitation will be comparatively small, since the added water will not amount to more than 5 per cent., and this precipitation may be easily removed from the "Acme" pans with a scraper or brush.

Henry W. Mauer—The instrument described by Mr. Cary is quite familiar to the refrigerating men, and you will probably recognize what he is driving at. Possibly in ice-making plants no occasion arises calling for the use of a psychrometer; nevertheless, the device has been on the market a good many years, and has been found very efficient for exceedingly close determination of moisture.

The President—Perhaps Mr. Burhorn will give us a word or two on cooling towers.

Edwin Burhorn—I have not as good a test plant as Mr. Shipley speaks about, and I have not experimented long enough to be able to present anything that I think would be of interest to the Society, but on one of the tests we are making we use thermometers which record the temperature of the water going to and coming from the tower every minute of the twenty-four hours. I do not know how often Mr. Hart took his readings, but the conditions vary so much during the day that it is important to know whether the readings were taken at the most favorable or unfavorable time, in order to get a fair average determination. We also find that we can cool the water from a high temperature, say 130° or 140°, down to the atmospheric temperature. The thermometric cooling depends also

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to a great extent on the way the tower is designed, that is, the amount of water distributed per square foot of tower. The efficiency also varies with the capacity of the tower. A small tower is more efficient per square foot than a large one, and all those points cannot very well be determined theoretically. It is a matter of practice, and we are trying to find out these things, and as soon as we get our observations in shape we expect to present them to the Society, and we hope they will be of interest.

B. Franklin Hart, Jr.—These observations were taken, as noted in my paper, by the brewery people themselves, in the regular course of their work, to see if the tower was doing the cooling called for by the guarantee, and they are particularly valuable on that account, for they cannot be open to the possible criticism of manipulation by those interested in securing good results.

E. N. Friedmann—How would Mr. Hart arrange a cooling tower where an ammonia condenser is used, and also a steam or surface condenser, where the temperature would be, say, 130° to 140°? Would he use one or two cooling towers; one for the ammonia and one for the steam condenser?

B. Franklin Hart, Jr.—In answering Mr. Friedmann's question I would state that we have found that the results are better if a separate tower is used for each function. The fact is that when the water for the ammonia condenser gets much above 80°, not exceeding 85° in temperature, the efficiency goes backward very fast, whereas for the steam condensing, under non-vacuum conditions, if the water be reduced to 100° it will be fairly efficient. The conditions of temperature are so different that it has been our advice to buyers to use two towers, one tower for each part of the work.

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No. 31.

OILY WATERS AND THEIR TREATMENT.

By Albert A. Cary, New York, N. Y.

(Member of the Society.)

The separation of oil from exhaust steam or from the water resulting from its condensation is a matter of great interest to all engineers. So disastrous have been the results from using such water in boilers that now in many large plants the water from this condensed steam is wasted, no attempt being made to return it to the boiler. In plants where the cost of city water runs from ten cents upward per thousand cubic feet such waste means a considerable loss, owing to the fact that fresh water from the main has to be constantly supplied to the boilers, whereas if the condensed steam from the engine could be used the cost of water for use in the boiler would be materially lessened.

In considering this problem it is well to bear in mind that there are many kinds of cylinder oil, some consisting entirely of mineral oil which has been deprived of its most volatile constituents, while other cylinder lubricants are composed of organic oils. This latter class of cylinder lubricants is seldom found in use at present, although largely used twenty-five to fifty years ago. At that time of lower steam pressure tallow was sometimes fed into the cylinder for a lubricant, but as it was found to be a constant source of trouble it was finally given up, as it was found that mineral oils could be used instead.

In the cheaper grades of cylinder oils we will generally find a mixture of mineral oil which has not been sufficiently deprived of its most volatile constituents, and this is mixed with some animal or vegetable oil to increase its viscosity. These cheap oils should never be used, as it will be found that they will vaporize at comparatively low temperatures, often considerably below the temperature of the steam, and with the most useful part thus rapidly carried off by the exhaust steam, the remainder forms a very poor lubricant, from the use of which we may look for a badly cut cylinder and a heavily oil-laden exhaust steam.

Very little of the oil used for lubricating steam cylinders is lost, even when the highest grades are used. A certain part performs its

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office as lubricant and then practically all is hurried along with the exhaust steam out of the cylinder.

After careful investigation I have found that this oil exists in exhaust steam in three different forms: First, as a vapor; second, as sub-divided particles of oil; third, it adheres to and forms a coating around the particles of condensed water existing in exhaust steam, forming what is known as the moisture in steam. The oil surrounds these particles of water just as the skin surrounds an orange, and it is surprising to see how tenaciously such oil clings to the surface of these water drops. When such globules of water with an oil coating are collected in a glass vessel the mass will have a peculiar grayish color, similar to diluted milk, and we will have what is commonly termed an emulsion of oil and water. Such an emulsion can also be formed, less perfectly, by placing water at a proper temperature in a bottle with a small amount of oil floating on its surface and shaking it so as to cause the water to separate into minute particles as they come in contact with the oil. By examining a sample of this emulsion under a miscroscope it will be seen that the mass is composed of a large number of small globules of water with an oil coating.

In selecting cylinder oil the following may furnish some idea as to the qualities it should have. It should stand heating to a temperature of not less than 475° F. before giving off a volatile vapor which will flash a match, which is termed a flash test, and it should have a burning point of at least 100° higher. It should also have a specific gravity between 0.9032 and 0.8860, and, further, it should not have a loss any greater than one-half of one per cent. when exposed for three hours to a dry temperature corresponding to the steam, say 350° F. It should be free from dirt, grit, lumps and specks; it should also be transparent or greenish or reddish, but not black, when spread as a thin film on glass and looked through toward the light.

All specific gravities are comparable at 60° F., but when the oil is tested, if it is not sufficiently liquid to flow easily, it should be warmed until it does and then be tested with the hydrometer, which should move easily and freely in the liquid. If the test temperature is greater than 60° F. it will be necessary to note the temperature and make a correction which would give us a corresponding specific gravity at 60° F. Tables to facilitate such corrections will be found in certain works on lubricating oil.

The statement of flash temperature attained in a flash test of oil as ordinarily obtained in a laboratory is very deceptive, because

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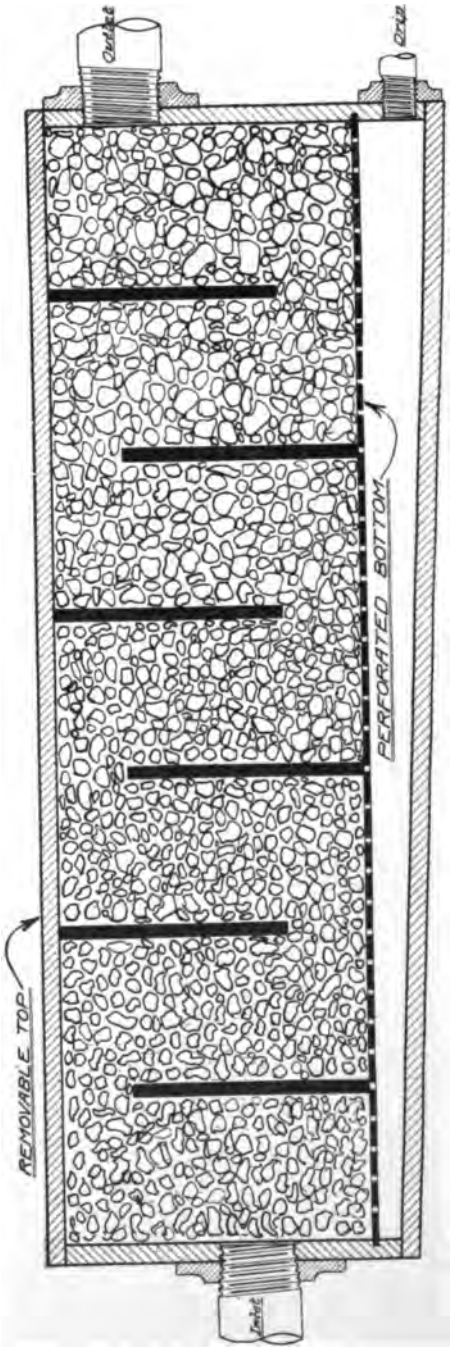

FIG. 1.—COKE-FILLED STEAM FILTER.

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the oil will actually vaporize when in contact with steam at a lower temperature than the flash point, as determined by the ordinary method of testing.

To illustrate: In an investigation I made to ascertain the cause of bulging in a boiler, I found that the water resulting from the condensation of the steam after passing through an excelsior filter was returned to the boiler. The cylinder oil was of a good quality, coming up to or exceeding all the requirements mentioned above. The flash test showed that the oil could be heated to 504° F. before flashing when tested by the ordinary method, but when I placed a sample on the surface of water in a small experimental boiler which I operated under 100 pounds gauge pressure, corresponding to 337.8° F., I found that a very large percentage of the oil passed off with the steam. This vapor was collected in the laboratory on the bottom of a glass beaker containing ice water. The beaker was held some two or three inches above the jet of steam escaping from the boiler outlet, and the steam and vapor, as it floated upward, struck against the bottom of the beaker, where the oil, vapor and steam were condensed and then carefully collected and subsequently tested with ether. During this test I collected very small globules of solid oil and also globules of oil-coated water in the tube of a glass condenser.

With these remarks concerning the various conditions in which oil is found in exhaust steam, we may look to the methods of separating it, first, from the steam, and, second, from the water of condensation, previous attempts to rob the steam of its oil not being considered in the latter case.

The methods of oil separation from steam may be classified under the following headings: Steam filtration; steam washing; precipitation by gravity, for which purpose the velocity of the steam must be considerably reduced for a short time during its flow; separation by use of oil catchers, which consist of specially prepared surfaces, such as baffle plates with corrugations or other irregular faces—also the use of wire screens placed in the path of the flowing steam, or by passing the steam through a chamber filled with suspended chains; precipitation of oil upon the surface of water; and separation by passing the oily steam through a material which has a greater affinity for oil than exists between a surface of water and the oil.

The methods of separating oil from the water resulting from the condensation of steam are as follows: Skimming; filtration;

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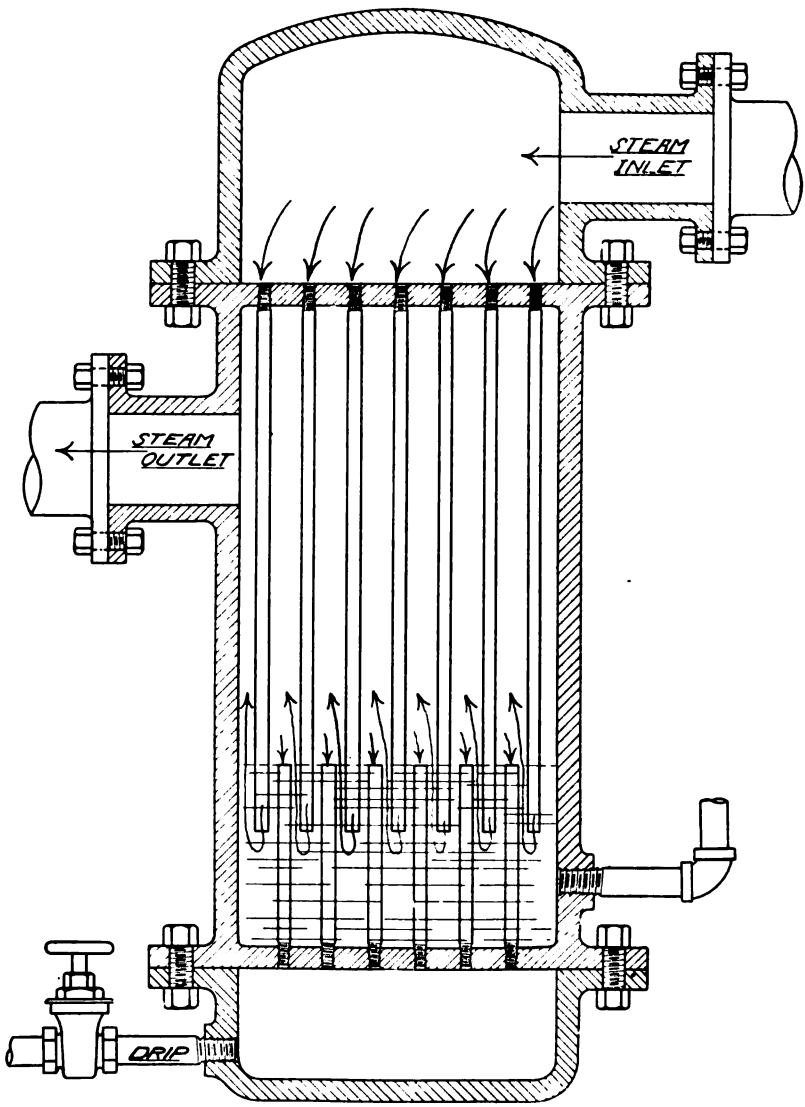

FIG. 2.—STEAM WASHER.

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treatment with chemicals and coagulants, followed by filtering; and use of oil absorbents mixed with the water.

Considering this subject under the headings given above, we first have:

Steam Filtration.—There have been many attempts to remove oil from exhaust steam by filters. A large variety of material is used as filtering mediums, such as blankets, sponges, coke, hay and excelsior. These are inclosed in a long circular or rectangular box (Fig. 1) fitted with baffle plates to force the steam to travel over and under the baffles from one end of the box to the other. Very fair results may be obtained when such filters are kept clean, but as the filter gradually becomes fouled with the oil less oil is retained, and either the filter becomes clogged so as to cause a back pressure on the engine or it allows large amounts of oil to pass.

When blankets and sponges are used they are taken out periodically and put through a cleansing process in a solution of caustic. Attempts have been made to clean oil-charged hay and excelsior by forcing a current of hot water through the filter in a reverse direction to that taken by the flowing steam. When coke is employed, very open and porous coke, such as can be obtained from gas houses, must be used. After this coke becomes clogged it is customary to shovel it out of the filter and burn it under the boilers, replacing it with a fresh supply.

It will be seen that by the methods of filtration described the globules of oil and also the drops of water carrying oil will have their passage retarded when the filter is in good condition; but the oil vapor, even under most favorable conditions, is apt to pass through the filters and continue on into the boiler.

Steam washers have been used for the separation of oil from steam with fairly good success in some plants. These washers (Fig. 2) consist of a vertical cylindrical tank having three chambers. The top chamber rests like a hat over the top of a tube plate. The tube plate (separating the top chamber from the central chamber) contains tubes which drop to within a short distance from the bottom of the central chamber and their lower open ends are immersed in water carried in the bottom of the central chamber, so that the steam when exhausted into the upper chamber is obliged to pass downward through the vertical tubes and then through the water in which they are submerged; the steam then bubbles upward through this water into the top of the central chamber, whence it passes out to the condenser. The bottom of the central chamber consists also of a tube plate with the tubes extending upward to the

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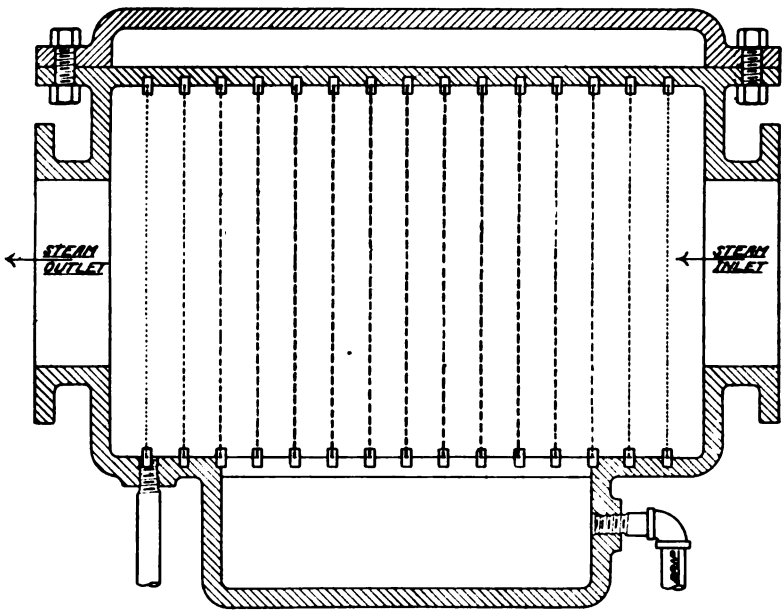

FIG. 3—INTERCEPTING SCREEN OIL FILTER.

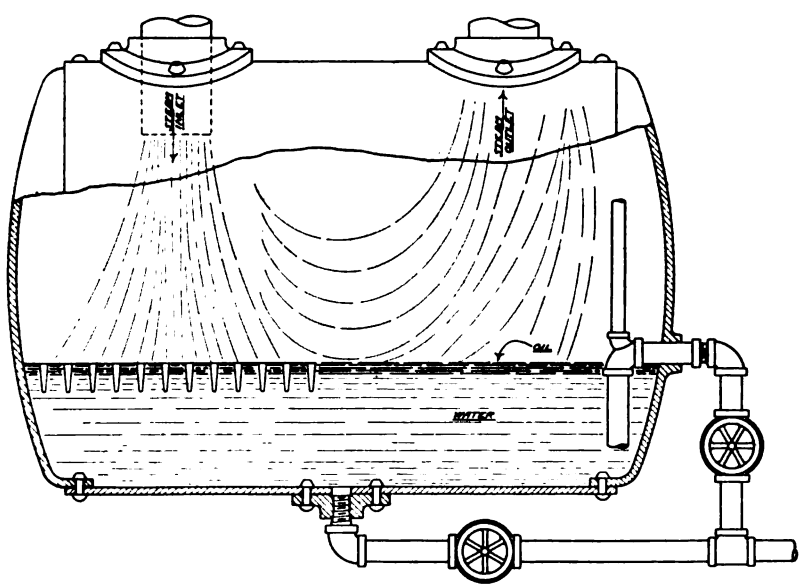

FIG. 4.—WATER SURFACE OIL SEPARATOR.

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surface of the water in the central chamber, and as fast as the condensed oily steam accumulates in this chamber it overflows, passing downward through these short vertical pipes into the bottom chamber, whence it is run off.

By the use of such a device the vapor, as well as the small particles of oil and water globules covered with oil, is forced to pass through the body of water, and providing this water is sufficiently cool, and has a sufficient volume, and ample circulation of the wash water occurs, very good results may be obtained.

Next, taking up the matter of *precipitation by gravity*. This class of separator has not proved as efficient as some of the other forms mentioned. Its working principle depends upon the reduction of velocity, or sudden change in the direction of flowing steam. Thus we find, in certain oil separators of this type, the steam flowing along a pipe of proper dimensions, which steam is suddenly discharged into a pipe or tank of considerably larger area, where its velocity is suddenly diminished.

This reduction in speed causes the suspended particles of oil and water to drop to the bottom of the large pipe or tank, just as suspended particles of sand or dirt are precipitated from the water of rapid-flowing brooks or rivers when it suddenly rushes into a large basin along the waterway.

Other separators of this type not only supply this enlarged chamber along the line of steam piping but also provide for sudden changes in the direction of the flow of the steam. These changes in direction also cause a difference in velocity, followed by a precipitation of suspended particles, as before described.

Special arrangements are usually made for entrapping the dropping suspended particles, which are usually discharged by gravity through a steam-trap arrangement.

It will be noted that this class of separator can only care for the particles of solid oil, water and oil-coated globules of water, while much of the oil in vapor form will pass through the apparatus and cause trouble beyond.

As regards *oil catchers*, I am afraid that I cannot endorse them highly, as I have not experienced very satisfactory results from their use. When some of these devices were perfectly clean and in good working order I have seen excellent results obtained by their use, but after they began to get foul the oil seemed to pass over their surfaces and accompany the outgoing steam. In these separators are found box-shaped castings, having irregular surfaces against which the steam is projected from the inlet pipe, the idea being that,

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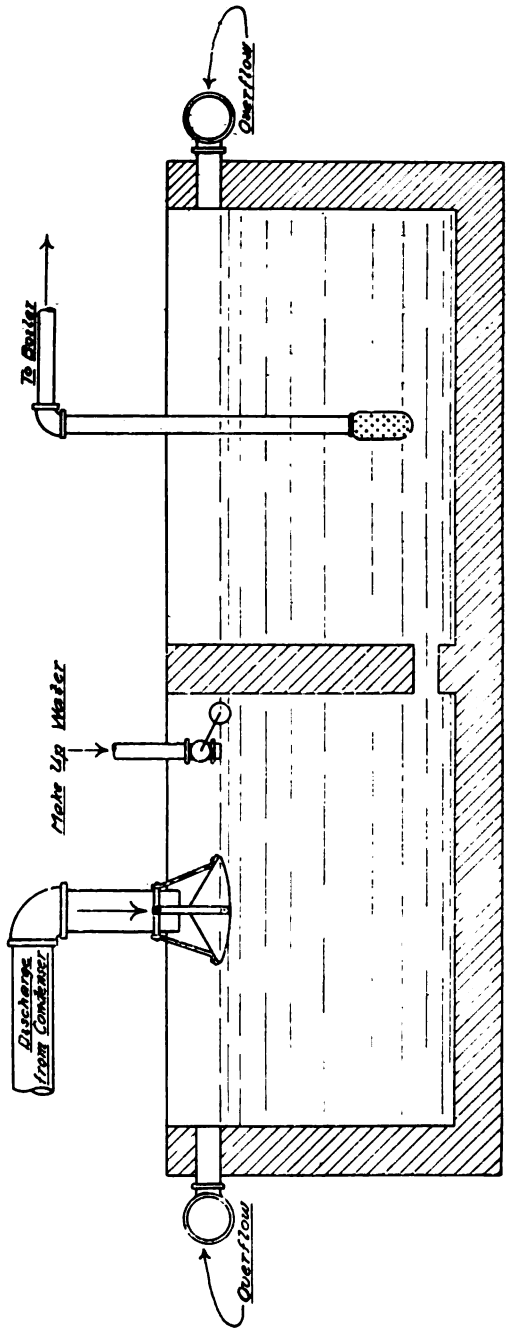

FIG. 5.—HOT-WELL ARRANGED AS OIL-SKIMMING TANK.

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when, owing to its sticky nature, the steam once reaches such surfaces, it will attach itself to them and run down their corrugations or along other irregular surfaces into channels prepared to allow the water and oil to flow.

In nearly all of these devices the area provided for the steam flow will be found much larger than the feeding steam pipe, for the purpose of allowing the heavier drops of water and oil to fall by gravitation from the steam which carries them.

In another form of this class of apparatus we find box-shaped castings, containing wire cloth (Fig. 3), generally of three or four different mesh, through which the steam is blown. Such devices depend upon the velocity of the steam passing through their enlarged areas, as well as the considerable surface presented to the exhaust steam by the wire forming the screens, on which the sticky oil is supposed to collect, and then works its way downward to the bottom of the trap, whence it is discharged.

In this device, in the upper cover of the trap, is a removable hood or cap which can be easily taken off and the various screens removed and cleaned, and thus very good provision is made for keeping these surfaces in an effective condition.

The steam traps containing suspended chains which hang from their upper surfaces work in a similar manner to the trap just described.

We now come to the subject of the *precipitation of oil on the surface of water*, which is very effective under proper working conditions. In this device (Fig. 4) we have what might be considered a small cylindrical boiler without tubes, placed horizontally, which is constantly kept about one-third full of cool water. The steam from the engine enters the top of this cylinder and is projected upon the surface of the water immediately below. I have already mentioned the tenacity with which oil clings to the surface of water, and advantage is taken of this fact in this apparatus.

The small particles of oil, the water particle surrounded by its envelope of oil, and the vapor are all thrown against the surface of this water by the entering force of exhaust steam, and as the cylinder is much larger in cross-sectional area than the steam pipe the exhaust steam has an opportunity to drop easily any of its suspended matter upon the surface of the water. The steam entering the tank from the top at one end leaves the tank at the opposite upper end. By this arrangement every opportunity for getting rid of its charge of oil is offered.

A grating placed at the level of the surface of the water, imme-

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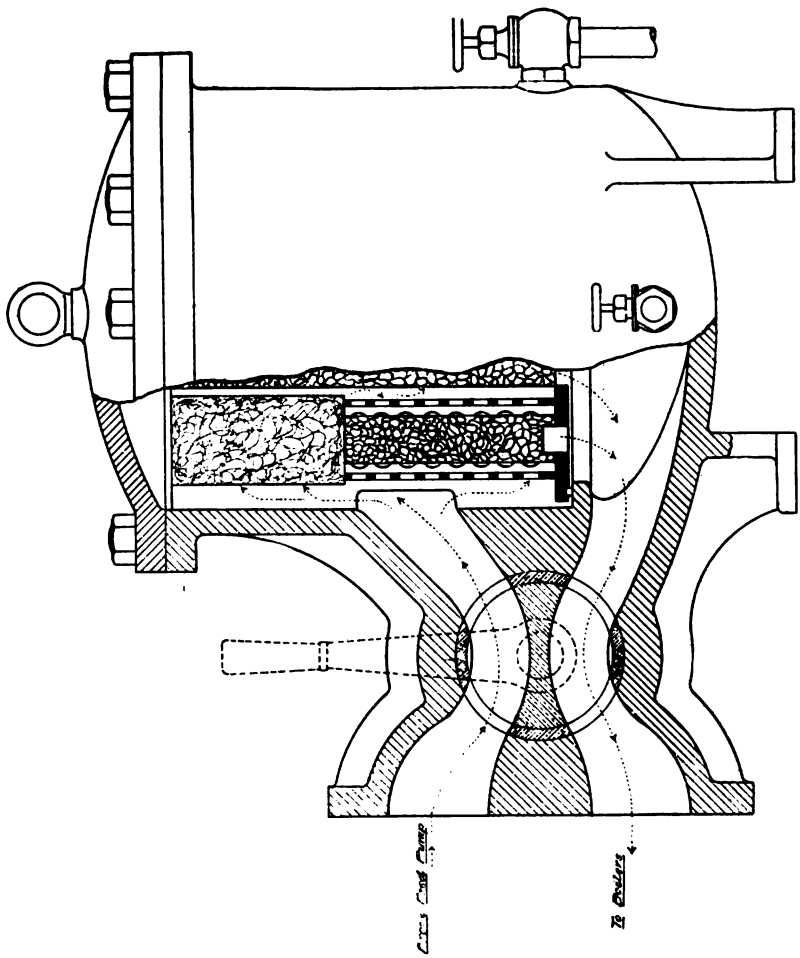

FIG. 6.—OIL FILTER.

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diately below the inlet steam pipe, is found to increase the efficiency of this apparatus, as without this grating the oil film and water at this position are agitated too vigorously to allow the oil to collect there.

The last classification of oil separation from steam is *separation by passing the oily steam through an oil-absorbing material.* This is an entirely new method of treatment which may be said to have only passed the experimental stage, but is introduced here merely to bring this paper up to date.

The material itself will be spoken of again at the end of this paper. I regret to state that, as the consulting engineer who has been called upon to investigate its properties, I cannot say more at present concerning it. I have found it to be a wonderful absorber of all kinds of oil, having a greater affinity for oil than has even the surface of water. It is an inexpensive mineral substance, and, when reduced to a sand-like size and form, the exhaust steam, when blown through it, will lose its contained oil, which leaves the steam and attaches itself firmly to the material, which may be either dry or mixed with water, so as to be used in a steam washer, and its capacity for taking up oil is very great.

I think I have now considered all the different methods in use on the separation of oil from exhaust steam, but in most plants no provision of this kind has been made to rob the steam of its oil, so the oil is allowed to pass through the condenser, and the resulting water flows on to the hot well.

As oily steam passes from the engine into the condenser, much of the vaporous oil unites with the condensing steam and forms an emulsion of oil and water. As the free oil is carried with the water of condensation and discharged, under more or less head, into the hot well, this agitated oil and water tend to unite still further in an emulsified condition, the same as the water and oil in the shaken bottle referred to previously.

Referring to the first method of separation of oil from water, namely, *skimming,* I will describe an apparatus designed by me some years ago to operate upon this principle. On reference to Fig. 5 it will be seen that the hot well consists of a tank with a central wall dividing it into two compartments. The water of condensation is delivered into the left chamber, flowing gently from the delivery pipe over a metal cone which prevents the incoming water from striking violently upon the surface of the tank water, which would cause further emulsification. The water thus introduced slides

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gently over the cone to the surface of the tank water, and thus facilitates the flotation of the free oil and oil-coated particles of water.

At the extreme left of this left-hand division of the hot well will be seen a large number of earthenware pipes through which a constant overflow of water from the surface of this well took place, carrying with it the oil which floated there. The balance of the condensed water then passed downward through a number of openings in the lower part of the central wall of the tank into the left-hand division, whence it was allowed to overflow through sewer-pipe connections, as a little oil was found to gather there upon the surface of the water in this second chamber. The end of the suction pipe to the boiler pump was placed near the bottom of this left-hand tank and equipped with a strainer. When in operation this apparatus worked fairly satisfactorily, but at times much oil would pass through the tanks to the boiler. A ball cock regulated the flow of fresh water into this skimming tank and always kept the water level up to a point where the water would constantly and slowly run off through the sewer-pipe connection shown.

Filtering hot well water is an unsatisfactory method of getting rid of the oil, although I know of some plants where it is claimed that fairly good results are obtained by this means. This practice is largely followed at sea, the materials used as filtering mediums being the same as those described for filtering oily steam. To this list may be added sand filter beds. Cleaning such filters is, at the best, a filthy job which will be avoided as much as possible by those upon whom this duty falls. If these filters are not kept clean they become worse than useless, for when anyone has a preventive of any ill he will depend upon its successful operation beyond a reasonable time.

One of the best forms of this class of filter is shown in Fig. 6. It consists of a cylindrical shell filled with a number of so-called cartridges which are interchangeable and easily removed and replaced. These cartridges are cylinders of perforated metal with an opening at the bottom. A cloth stocking-like envelope is pulled over the outside of the perforated cylinders, acting as the first filtering medium, while the interior is filled with a fibrous material which also acts as a filter. The oily water is sent from the condenser into a closed chamber containing these cartridges, and after passing through the double filter the remaining clarified water is discharged, through the bottom opening of the cartridges, into a receiving vessel forming the bottom of the apparatus.

Passing to the treatment of oily water with *chemicals and coagulants,* the chemical treatment of water to remove oil has thus far

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proved a failure. If animal or vegetable oils alone were used we could treat the water carrying them with soda or potash and lime and thus first saponify the oil. The resulting soap would react with the lime and form an insoluble curd, which would be removed by skimming or filtration. But the greater percentage of cylinder oils are composed of mineral oils, the only satisfactory solvent of which is ether, which is too expensive and too volatile for practical use, although I have heard of a process for using it in oily water, and afterward recovering it by partial distillation and condensing, but this is rather impractical and needs no further attention here.

The use of coagulants for the removal of oil from water has been tried on a large scale in a number of plants with fair success. Such coagulants as alum or aluminum sulphate and green vitriol or sulphate of iron react with water and form a sticky or mucilaginous material which floats to the surface of the water, sticking to and carrying with it any foreign material. In this manner such coagulants carry oil with them, thus cleansing the water more or less perfectly of this troublesome material.

The great danger connected with the use of these sulphates arises from their reaction in water, which not only forms the flocculent sticky material, but also sulphuric acid, which would prove more dangerous in boilers than the oil itself. To neutralize this acid, it is necessary to treat the water with caustic soda. This treatment results in the formation of sulphate of soda, which remains in solution, unless greatly concentrated, at all ordinary boiler temperatures. This harmful concentration can be avoided by the frequent "blowing off" of the boiler.

The last method listed for the treatment of oily water of condensation is *the use of oil absorbents mixed with the water.* This is not a chemical but rather a mechanical treatment. My attention was first called to this method in 1900 by Mr. N. O. Goldsmith, of Cincinnati. Experiments made along certain lines gave me results which were perfect in most cases, but failed to a small extent in other tests. Mr. Goldsmith employed a process similar to an English invention known as the Anderson process for purifying potable water. I do not think that Mr. Anderson ever employed this method for oil elimination. The material used for absorbing oil from the water was hydrous oxide of iron ($2Fe_2O_3 3H_2O$). The principal objection to the use of this process is the necessity of preparing this hydrated ferric oxide in sufficiently large quantities to meet the requirements.

In connection with the use of condensed steam one fortunate

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fact is that there is a very large amount of air dissolved in this water, the presence of this air requiring the use of large air pumps in condensing plants. Atmospheric air contains nitrogen and oxygen in the proportion of about 4 to 1. On account of the greater solubility of oxygen in water the dissolved air in water has a proportion of 1 volume of oxygen to 1 87/100 volumes of nitrogen. With this increased amount of oxygen, with the warmth and moisture present, a very active rusting action takes place when the oxygenated water comes in contact with bright iron chips from lathes, etc. Advantage is taken of this in the modified Anderson process. The condensed steam, or water, is led into a long, cylindrical, revolving tumbling barrel, filled with bright iron chips, etc. As this iron oxidizes, the revolving tumbling barrel rubs its contents, one piece against the other, and thus throws off the iron oxide, which immediately absorbs whatever oil is present. The bright chips, left behind, quickly oxidize again, and thus the process continues.

A little over a year ago I had a new material for oil absorption presented to me for investigation, and found, after thorough investigation, that it fulfilled all requirements most satisfactorily. It was the first absolutely satisfactory oil-extracting method I have found after years of investigation.

The material, which I cannot describe in detail at this time, is obtained from a natural rock deposit. It is easily obtainable in large quantities and is not expensive. Generally speaking, all that is necessary in treating oily water with this material is a thorough mixing device which will distribute the light feather-like material throughout the water of condensation. All the oil is then found to leave the water and attach itself to this material, which has a very large capacity for taking up oil. The oil-laden substance is subsequently removed from the water by a rapid filtering process, and the resulting water, after proper treatment by this process, is perfectly clear and free from the taste of oil.

So effective is this material that the quantity used for oil extraction is but one-twentieth of one per cent. of the weight of the water itself, and it can be used a great number of times.

DISCUSSION.

John C. Sparks—I have had some experience in testing water that has gone through an oil filter. I found such filters were not very efficient. In New York City I went to test a filter that was filtering oil out of water, and on about the second or third day I noticed that the water drawn from the filter smelled very much of

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kerosene, and I said to the engineer, "Do you put kerosene in this water?" He answered, "Yes; I put in a quart of kerosene every Friday." I think it cost $800 to fix that filter. He added oil to the boiler every Friday, and he was surprised to find the oil coming over with the vapor of steam at a lower temperature than the flash point of the oil. As a matter of fact, the flash point is the temperature at which there will be sufficient vapor to cause a flash, but there is much vapor that comes off before this temperature, and if that vapor could be collected and ignited it would be found that the oil would flash at a lower temperature.

Mr. Cary said that if the oil that came off was animal or vegetable oil it could be saponified, and then filtered out. I do not understand that, because any soap that is made is largely soluble. I do not see how it could be removed by filtration if a soluble soap was formed.

Albert A. Cary—I appreciate Mr. Sparks's remarks concerning oil vapor being carried over with the steam. I have a small experimental boiler holding about a gallon of water, that I used in an oil investigation which Mr. Shipley knows something about. During these investigations I desired to find the effect resulting from heating oil in the presence of moisture. I placed a small vessel containing oil inside of this boiler, which was partly filled with water, and raised it to different temperatures, making a succession of observations. I succeeded in several of these tests in carrying oil over in the steam at lower temperatures than the flash point of the oil—in some cases as much as 90 per cent. of all the oil was carried over in the steam and collected afterward. So far as the saponifying method is concerned, what Mr. Sparks said is, of course, true, as the soda or potash soap is soluble, but by the addition of lime a curd is formed, which is retained on the surface of the filter. This is not a method I advocate, but is presented here on account of its being a process that has been in use in this country.

E. N. Friedmann—In ice-making plants, of course, we want to get rid of the oil and do not want to lose more of the steam in condensation than is necessary. Will Mr. Cary tell us which system is the most efficient in getting rid of the oil?

Albert A. Cary—I have covered a very extensive subject in a very general sort of way. It is difficult to say without an investigation which is the most efficient process. Nearly every plant has its peculiar conditions, all of which must be taken into consideration and studied. If I had all the conditions of any one plant placed

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before me I might be able to answer Mr. Friedmann's question properly; otherwise, I am afraid I could not.

L. Howard Jenks—Mr. Cary has covered such a large variety of separators that there remains but one to complete the list, and that is the mechanical separation of the oil and water, as is done by the cream separator, driven at a high velocity. The oil can be separated from the water to a great extent, but it has not been accomplished perfectly, although there is a large quantity of oil separated. Of course, the oil being very hot is a favorable condition to the mechanical separation.

Albert A. Cary—This process has been experimented with in this city, and I understand that it has not been wholly a success. The De Laval cream separator has been very successful in separating cream, and there is no reason why something of this kind could not be worked out to do equally well with oil, if the oil and water occurred in similar relations to each other as we find in the fluid composed of milk and cream. The oil could be thrown out if free oil could be brought to the surface the same as cream rises to the surface of milk, but the great trouble in the oil and water mixture is due to the emulsion of the oil and water. Here we have a mass composed of very small globules of water surrounded with a skin of oil that is almost of the same specific gravity as the water itself, and the surface tension of the oil on the water may be very great. It is largely due to this condition that we find much difficulty in this method of centrifugal separation. On that account I am afraid that this method will never be a wonderful success. The solid oil separating from the water may, however, be thus removed. The removal of oil in emulsion is another matter.

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No. 32.

Discussion of the Topic—WHAT IS THE BEST METHOD OF THAWING OFF PLATE ICE?

L. Howard Jenks—It depends on whether it is a direct expansion plate or a brine plate. In the former, hot gas is turned into the plate coil, and in the case of a brine plate warm brine is pumped through the plates. These are the only methods I know.

John E. Starr—I do not think I have discovered the best method of thawing off plate ice. I do not know of anything I can say very positively on this subject. In a plant using direct expansion coils the best method is to introduce a hot gas into the coil. This does very well so far as the plate is concerned. Some plants use for the side of the plate simply a board set at some little distance from its edge, some 10 or 12 inches, and this board comes up even with the plate. The ice will usually come up easy from the bottom board. I know of one instance where considerable success was obtained by treating the bottom board with a coating of paraffine, rubbing it very thoroughly into the board. In this case the ice came off very nicely without any bottom thawing. This is the only new thing of that kind I know of, over and above the ordinary practice of thawing off the ice.

I think we are all pretty familiar with a number of methods, and as the time is short I only mention the use of paraffine on the bottom of the plate as being something not of general knowledge.

Henry Torrance, Jr.—I think that the problem of thawing off the edges of plate ice is not yet solved. The great difficulty is that one has to make a close joint between the end plates, and there is apt to be a sliver of ice there, and I notice that that ice is very hard; I should say that its tensile strength is greater than ordinary ice. It is difficult to get the corners of the ironwork made nicely in the ordinary construction of the plate. There is no difficulty generally in thawing off the ice from the main plate. As a rule that can be done quite quickly. Generally it is necessary to have three pipes on the side plates and I have tried it with two. It is difficult. Three will do it fairly well, but even then the trouble is with the corners.

John E. Starr—Have any of the members had any experience

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in putting the thawing pipes, the small pipes at the bottom of the tank, in concrete instead of using a base plate?

Henry Torrance, Jr.—I have seen concrete used to fill in, but I think it would be too brittle unless made into a solid wall. I think the concrete wall would be too brittle unless used with a lining.

Irving Warner—We use the direct expansion system at our plant, and while, as the gentleman says, it is quite easy to thaw off the main plates, the ends and the bottom are the sticking points.

Our method, which we have fixed up on a few of our tanks, is quite satisfactory. It is to have a three-fourths of an inch coil of pipe connected with the steam line. It goes down one end across the bottom and up the other end, where it spouts over into the waste. In order to prevent the pipes from freezing during freezing processes, the bottom pipes are slightly inclined away from the source of steam supply, and at that point we have inserted a T and little brass cocks. The efficiency of the apparatus depends, of course, upon the men going around and opening these cocks, and being ready to close them when thawing begins.

Thus far we have had no trouble. The men have opened these cocks, and the apparatus drained itself perfectly of water. The freezing takes place without bursting the pipes. If the pipes burst we would have trouble. Then there is the other arrangement we have in general use, merely to have the steam go down one side and out the bottom. In that case the pipes are open all the time. To thaw off the opposite side we have a galvanized plate set off a distance of about an inch and a quarter. That space is an inch and a quarter by probably 12 inches and it is filled with ice in freezing, and we suffer that loss each time, because we melt that out by merely running a three-quarter inch pipe with a T on the end, just running it down that space, and melting out the ice. It warms the galvanized plates enough to free it of the plate itself.

In order to prevent the warming up of the rest of the water in the tanks (which are 28 inches between plates), we drain them first, running into a special tank for that purpose, and letting the cold water run back again, because if we run the steam down this way we would warm the water up, and not only lose the water but in a short time it would make a loss on the main plate of ice. If anyone does not quite understand the idea of the matter I will be pleased to go into it further.

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No. 33.

Discussion of the Topic—HOW CAN LEAKAGE BE PREVENTED IN CELLULAR BRINE PLATES?

Karl Wegemann—I do not know that I have investigated the subject, but I would suggest that probably welding the plates would prevent the leakage. Further than that I do not know of any method of preventing leakage.

L. Howard Jenks—How does Mr. Wegemann propose to weld two sheets of iron that have to be kept an equal distance apart, side by side, without introducing stay bolts to resist the pressure of the water in the water tank when the brine is withdrawn?

Gardner T. Voorhees—What is a cellular plate?

The President—I will call upon Chairman Starr of the Programme Committee to explain that.

John E. Starr—Mr. President, I think I can answer the question, although I am sorry to confess that I had very little to do with making up this programme. I think it was a very good thing that my involuntary absence led to getting up such a good programme. A cellular plate, as I understand it, is a plate made of iron or steel without piping; in other words, practically a hollow plate tank, say the width of the cake, 16 or 17 feet wide by 10 or 11 feet deep, and about 4 inches thick, the brine being circulated in the interior of the plate, instead of the more usual method of circulating through pipes with plates on each side. As the question of welding has come up, I may say that there are some recent developments in welding that would make it perhaps possible to weld a plate, even at the ends, and perhaps in that way make a tight plate. There are not so many cellular plates in use as the regular coil method, with the plates on each side.

L. Howard Jenks—I think the reason that there are not more cellular plates with the brine system of plate ice making is on account of the difficulties in making a satisfactory plate. There is, of course, the necessity of keeping the plate at a uniform thickness of 3 or 4 inches all the way down, to withstand the pressure of the water, and also the pressure of the brine on the inside when the water has dropped down below the level of the brine. The difficulty has been in using staybolts or channel iron, put in in the

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ordinary way. The contraction and expansion being very great, it is quite difficult to keep these plates tight and to prevent the leaking of the fluid or the brine, as the case might be, around these staybolts or rivets. If there is any possibility by the new method, which I think Mr. Starr referred to, of welding channel irons or staybolts that would keep these plates tight, this type of plate would then have a great advantage over the method now in vogue, of using a pipe or a coil with a plate on each side. The advantage of the cell is very obvious, but the difficulty in making, constructing and maintaining it tight is very great.

Gardner T. Voorhees—I would like to ask someone who has used the cellular plate, why there is any advantage in using it over and above a coil pipe with thin iron on each side—where the advantage comes in, whether it is in the cheapness or in the operation, or what?

Edgar Penney—I can answer that in part. In an ordinary plate, consisting of a continuous coil with a plate bolted on on each side, the freezing begins immediately in front of the pipe, giving the ice surface a washboard corrugation effect, which is gradually eliminated as the cake grows. Now, a tight brine cell, with a uniform circulation of brine, gives a freezing surface as cold in one place as in another, and the growth of ice proceeds evenly. With brine you can regulate the temperature and then regulate the growth of the ice so that it does not freeze thicker in one place than another. The brine cell is frequently 16 feet long, 9 feet high and at intervals there are internal stays, something like the side of a boiler firebox. Now, the trouble is that these stays sometimes give 'way and allow the brine to leak through to the freezing surfaces. The consequence is that escaping brine eats a hole through the plate of ice and you soon may have an opening that you could stick your arm through. Keeping these cells tight is, however, the same kind of a problem as keeping the firebox of a locomotive boiler tight; the contracting by cold may cause buckling of the freezing plates, which, of course, strains these stays. One method of constructing cells is to take two plates, preferably of three-sixteenths of an inch thick iron, although in getting so large a sheet it is usually nearer a quarter or five-sixteenths of an inch thick. Channel irons riveted at intervals of, say, 24 inches are used. These channel irons run vertically, from top to bottom, with countersunk riveting through the plates, putting in as many rivets as you please. You then eliminate the problem of screw stays. Of course, this is the ordinary boiler construction.

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John E. Starr—Is that a suggestion or a matter of fact?

Edgar Penney—A matter of fact. Another idea is as follows: Clips can be riveted at intervals on the inner surface of the plates engaging a piece of I-beam placed between these clips. These allow expansion and contraction while holding the cell from spreading. When the ice is taken from the compartment of course the water is lowered and, the brine cell being full of brine, you have the hydrostatic pressure of the brine column acting on the sides of the freezing plate, thus requiring some sort of a stay. Sometimes the brine is drawn out, the cell being empty and the compartment full, so that the plate has to be stayed to resist both internal and external pressures. The principal trouble with screwed staybolts is that the threaded surface gives 'way or strips the tapped holes in the iron. The substitution of the clips described allows a certain amount of give and take and so eliminates this difficulty.

Gardner T. Voorhees—My experience this summer in a large plant shows that, even though the ice freezes at first in corrugations on the pipe coil plate, it all evens out in the end, and unless the cell just described is very much cheaper than the pipes and plates, I do not see that there is any advantage in using the cellular plates.

Edgar Penney—What do you use in those pipes—brine?

Gardner T. Voorhees—Yes.

Edgar Penney—How many feet of pipe do you pass it through?

Gardner T. Voorhees—About twenty-four 2-inch pipes, each about 20 feet long.

Edgar Penney—What is the difference in the temperature of the inlet and outlet of the coil?

Gardner T. Voorhees—About two or three degrees, according to conditions.

Edgar Penney—Then the coldest brine will be on top, and you will get wedge-shaped ice; one end of the cell is cooler than the other and freezes the ice more quickly.

Gardner T. Voorhees—There is another feature, which is that the top part of the cell has more exposure to radiation than the lower part.

Edgar Penney—In open brine cells, where you have a space of 3 inches, you can handle the brine at low pressure and secure a uniform condition throughout the length and breadth of the plates. You can regulate the temperature so that you can secure a more uniform cake of ice. You can regulate the condition in the one case better than in the other.

Gardner T. Voorhees—If that is so, then if the plate would not

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cost more, it might be better, but I have never seen any plate ice but what was more or less round on top.

Edgar Penney—That would not be so unless there was a leakage of water against the cell in the compartment.

L. Howard Jenks—I might say, if the gentleman would bore a hole at the proper level in his water tank, so that the ice in expanding would not raise the level of the water in the tank, he would get a perfectly square top. I think he might have trouble in getting a square bottom, but the top would be perfectly square.

Henry Torrance, Jr.—There is no particular difficulty with the coil plate. The ice will be pretty nearly flat, but there is a certain amount of friction to be overcome in pumping the brine through it, and I do not think the ice freezes as fast as it does on a cellular surface, unless the coils are very close together. When the ice starts to freeze on the plates, there will probably be about three-sixteenths of an inch of ice immediately in front of the coils before there is any on the surface between the coils, and when you melt the ice off from the plate you will find that the ice varies about three-sixteenths of an inch; that is, the corrugations will be about three-sixteenths of an inch deep, but it does not affect the block commercially in any way.

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No. 34.

Discussion of the Topic—WHAT PRECAUTIONS ARE NECESSARY TO TEST SAFELY AN OLD COMPRESSION SYSTEM WITH AIR?

E. N. Friedmann—All that I know is what has happened to us by not taking precautions. I only know that in a case where a plant has been used and ammonia and oil have been in the system it is a dangerous thing to test with air. It seems that when you get to a certain pressure a combination of the vapor of the oil, a little ammonia possibly, and the air forms an explosive mixture. Sometimes by getting enough compression it ignites, sometimes by simply mechanical means. I remember a case years ago in the West, where I was in charge of the erecting of machines and had occasion to test ammonia condensers. I asked an employee to carry out my instructions while I was away. I called up by telephone, asking the operator to call this man to the 'phone to find out if he had carried out my instructions, and the answer came very promptly, "He has blown them up already," and so he had. Fortunately the men were standing at either end, and the explosion took place in the middle of the pipes. The engineer said he had had 180 pounds of pressure on, that everything was going very smoothly, and all at once it let go. The force of the explosion was extremely great, so much so that a piece of iron about three-eighths of an inch square, which had been blown clean through a 2-inch pipe, stuck in a second pipe. Those two pipes were about three-sixteenths of an inch thick, so it was forced through iron more than three-eighths of an inch thick.

As to the question of prevention, I would never test any system that has been charged with ammonia and oil under air pressure. Another reason is that I do not think the air pressure shows very much anyway. You could possibly find out where bolts or washers have been forgotten, but when it comes to the real test it is with ammonia, and I believe that under a test of 15 pounds of ammonia pressure you will find more than under 150 pounds of air.

R. L. Shipman—I do not believe there is any material danger in testing condensers with air, even though they have been charged with ammonia in oil. The explosion comes from the explosive

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mixture in the compressor itself. That is formed by using a low volatile oil. If you use cylinder oil you will not have explosions. Ammonia oil as used in ammonia compressors has a low flash point, and volatilizes at a low temperature and becomes explosive. I do not believe there is any danger of pumping up 300 pounds of air pressure, and I believe air should be required to test out the tightness and solidity of all joints. Gaskets are as likely to blow out in an old plant as they are in a new, and probably a good deal more likely.

Thomas Shipley—Mr. President, I have tested a good many plants myself. I have had a good many more tested where I was responsible for them, and I was never afraid to test them with air. The trouble you have with air is where you have a machine using a large quantity of oil. I have taken a De La Vergne system that contained barrels of oil, and I blew the oil out with air, and it did not blow up, because in the compressor I was using the oil had been eliminated. The source of trouble is in the compressor itself and not in what is in the coils. In my judgment it is good practice to blow out the coils with air, and I do not believe you can do much good by blowing out coils with 10 pounds of ammonia. That is only good for the ammonia manufacturers. It takes a good pressure to blow out the dirt in the coils. Our company makes a practice of cleaning out the coils with air, and we have never had an explosion, although we have put out about a thousand machines since I entered the employment of the York Manufacturing Company. Furthermore, I never heard of the Frick Company having any trouble of this kind while I was with it, which was a number of years. I handled a goodly number of the company's machines, and always blew the systems out with air.

The cause of the explosion which occurs when compressing air is the use of a low fire test oil in the compressor, and double-acting machines are the only ones I ever knew of where explosions of this kind have occurred.

The President—This subject has particular reference to old systems—those which have been in use a number of years—and not to new plants which have been operated for the first time simply to ascertain the tightness of the joints. I believe that a few years ago there was a misapprehension in the minds of some that there was danger from oil and ammonia and air, as some explosions had occurred during the pumping of air into old systems. Whether the real cause of these explosions was ever determined I do not know. Probably not, but I think that most engineers when pumping air

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into the system take some sort of precaution to prevent the temperature of the discharge from the compressor from becoming too high. They keep their cylinders quite cool; circulate water around the compressors if they have water jackets, and sometimes put ice on them; but I think the topic has reference specially to old systems, where there is an accumulation of oil and other things which require blowing out.

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No. 35.

Discussion of the Topic—EXPERIENCE WITH DIFFERENT FORMS OF PISTON ROD PACKINGS.

O. J. Morris—I think this a very important matter, and while I have no data at hand on piston packing, ammonia rod packing I do know, and every other practical man that has to do with the testing and operating of ice machines knows that this is one of the most important things with which the engineer has to deal. I want a packing that will hold under all conditions. Possibly a little adjustment—yes, we will have to allow that—but I want to know if anybody knows anything about a packing that will hold the dry gas and then hold wet gas on the same conditions, and under the same temperature.

I heard a gentleman say yesterday in private conversation that the man had not been born yet that could build a packing that could hold ammonia without adjusting, the machine working dry and then working wet. If anyone knows that such a packing can be built and can be used successfully and practically, I would like to hear from him.

R. L. Shipman—I had a little experience one time with a vertical single-acting machine. The practice had been to remove the packing from the stuffing box once a week, using a rubber cloth insertion packing, subject to about 210 pounds head pressure and about 15 pounds back pressure. I experimented considerably with the packing myself and used solid rubber that would run for periods of about four weeks without removing if it received the necessary attention. Solid rubber is very sensitive to temperature, and if the temperature of the stuffing box changes materially as liquid comes in the stuffing box must be adjusted. But if you give it the necessary attention solid rubber is very good even for dry compression. This was a dry compression machine.

In the course of investigation I visited a large packing plant, and the assistant chief engineer, a man of about twelve years' experience, showed me around, and I told him my trouble with packing and he gave me his method, which was to take the cloth insertion packing and put two or three rings in each end of the stuffing box and put in two or three rings of flax-faced packing with a rubber

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back on each side of the lantern gland. I tried that combination, and it lasted about twice as long as any other packing ever used on that machine, being very satisfactory. The reason for this is that the flax-face allows the oil to be distributed much better over the rods, while the cloth insertion rubber packing holds the two ends, to prevent the gas coming through the oil and the gauze.

Edgar Penney—My suggestion is this: the condition of the piston rod is quite as important as the packing.

L. Williams—With our trade on board ship we have packing subjected to rather hard usage. We run our machines on every voyage about ten days, and I have found that solid and sectional rings of Garlock packing give the best results. I put the solid ones against the gland and neck bushings and it has to be very carefully adjusted. If the machine is allowed to run warm or cold, the gas either begins to blow or else the packing will swell and cut the rod, but I found that this packing will last about three months and give good satisfaction. When replacing it I put the new packing on the inside and let the outside series of packing run longer. These machines work with about 240 pounds of head pressure and are double-acting.

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No. 36.

Discussion of the Topic—IS THERE ANY BETTER METHOD OF MAKING CAN ICE THAN THE USUAL PLAN OF SUBMERGING CANS IN BRINE?

Thomas Shipley—I do not know that I can give you any more information than most of you have in regard to making ice by the can system. The ordinary can system is about as good a way as I know of to make ice. Fig. 1 shows the Ulrich system, where air is blown up through the water. It is to purify the water more particularly than anything else. In the double can or Vaile system, Fig. 2, that is, an individual circulation for each can, you can get more ice per square foot of can surface than you can with the ordinary can system. A great many other things are to be taken into consideration besides the efficiency of the surfaces, which those who have used it have possibly found out, so that I believe that the ordinary method of making can ice is nearly as good as anything now in use.

There are two or three improvements in this system that I have in mind that our company will possibly adopt, or put some plant out on a particular system, within a year or so, after we get our wind. We are so busy now that it would be foolish to talk about new things. We are too busy getting out the old ones, but if Mr. Pilsbry and Mr. Strickler will let me, I will make one some day that I believe will give good results. We look to these gentleman to do most of the selling, and they object to any funny stunts, and I consult them when we come to these points. I expect to win them over, to show them that we expect to sell cheaper, and then we will show you a system that will, I believe, beat the ordinary can system, but to-day I believe the can system is the best way of making ice.

D. S. Jacobus—Mr. Vaile makes an 800-pound cake and he says that the ice is more salable than that from the smaller cans. The ice is hard and clear. The larger cans are filled as readily as the smaller cans. On drawing the ice the brine is shut off from the outer can and the amount of brine remaining in the outer can only partly fills it. On introducing an empty inner can the top projects only a short distance above the outer can and the inner can falls slowly as it is filled.

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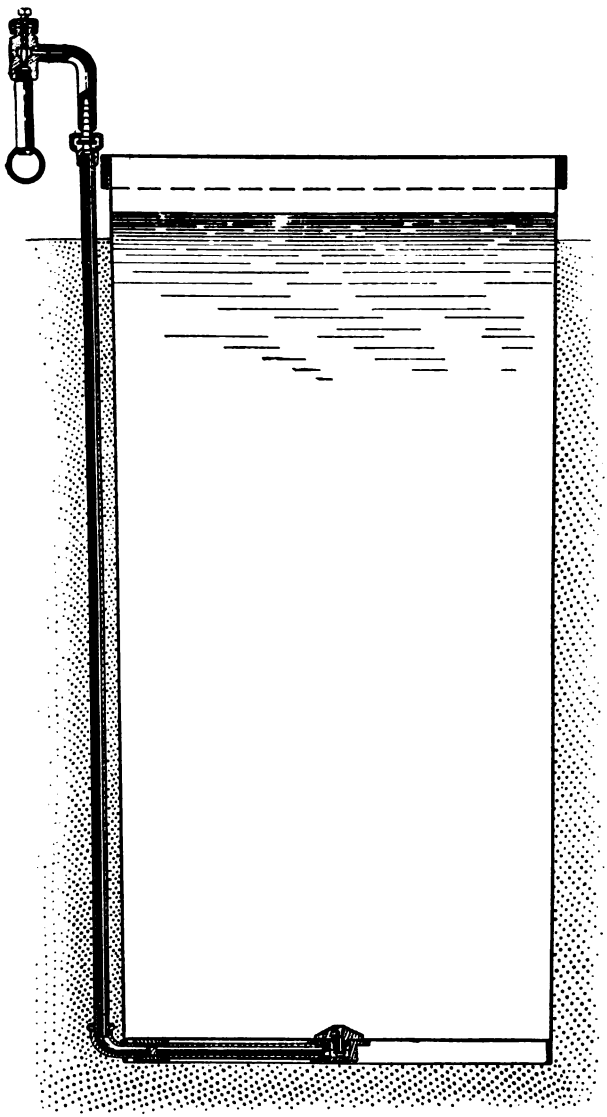

FIG. 1.—SECTIONAL VIEW OF ULRICH ICE CAN.

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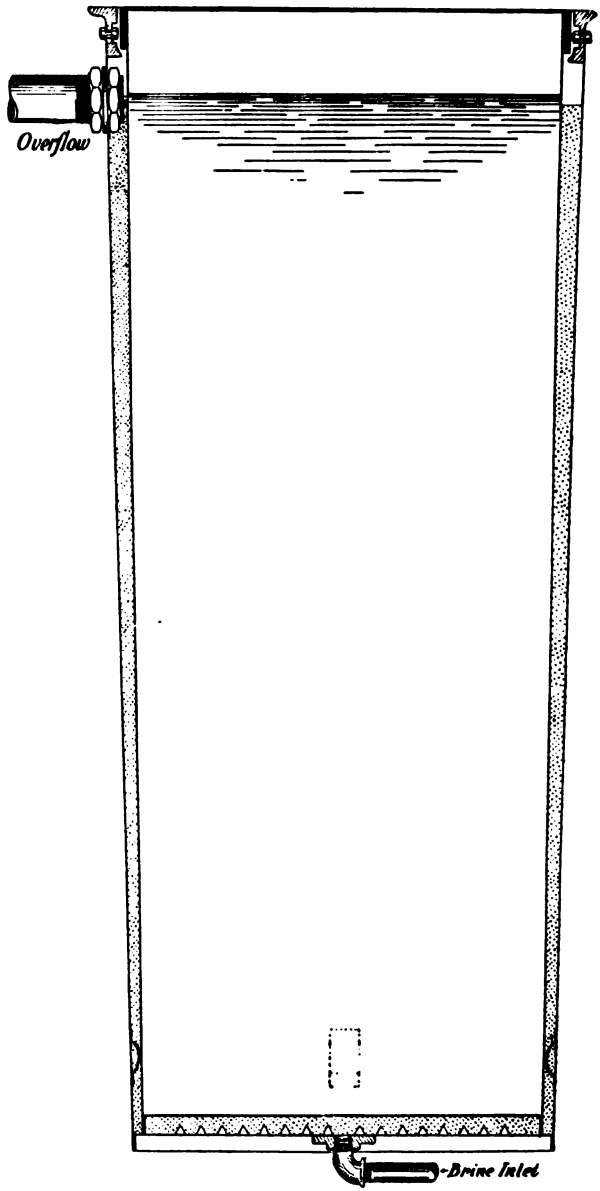

FIG. 2.—SECTIONAL VIEW OF VAILE ICE CAN.

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The President—I do not see why an 800-pound cake could not be manufactured by building the tank deep enough, just as well as by the apparatus described.

Thomas Shipley—You get an individual circulation, and you can produce more ice per can by that system than is possible by the can system. The greatest difficulty, however, with that kind of system is that you get the ice so cold that the fluctuations of the temperature of the brine itself will crack the ice right in the can, and it is a pretty hard proposition, as a matter of fact, to handle this ice, to harvest it and get salable ice.

The President—Then you get much more rapid circulation, much more efficiency of surface, in an apparatus like that, but there is hardly enough volume of brine to keep the temperature uniform.

Thomas Shipley—I mean of course that any change in the temperature is felt very quickly, not having sufficient volume to keep the temperature uniform, so that a little change will expand the surface and crack the ice.

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No. 37.

Discussion of the Topic—CONCRETE CONSTRUCTION FOR ICE TANKS.

J. S. Louis—Our company has had considerable experience in using concrete tanks. We did not put in the tanks ourselves, as we think it is much better to let the purchaser contract for them, but our experience has been good, bad and indifferent. We have recently installed a plant in an old power house. A bed of 8 inches of cinders was used, on which was placed a half inch of cement; 3 inches of cork went on top of that, and on top of the cork 5 inches of concrete. In this concrete were laid half-inch twisted bars, such as are used in concrete construction, on 6 inches of cinders. The concrete was allowed to rest for about three weeks, after which a very diluted acid was used to cut off the gloss. This gloss finish having been cut off allowed the three-quarters of an inch of cement finish to adhere to the concrete. The sides of the tank were constructed practically the same, with the exception that the bottom portion of cinders and the cork were laid up against a brick wall. We found in the first week that the tank leaked about one inch, and in the second week about the same amount, but this leakage was taken up by throwing bran in the solution. The bran, of course, found the crevices and stopped up any leaks. This tank has been used all summer and has proved satisfactory. Some three or four years ago we put in a plant in which was used a concrete tank with hollow tile insulation, which proved to be very efficient. Last year, in the South, we installed a plant where a concrete tank was used, and a few days before my departure for the East we had a letter from our customers inquiring as to the price of a steel tank to put inside this one. So it resolves itself into the inference that if the concrete tank is constructed properly it is a good proposition. We found it would cost from 10 to 15 per cent. less than the steel tank, and I believe it is entirely a matter of having the tank built by such companies as understand concrete construction.

Irving Warner—We have no concrete tanks, but when we need any we are going to build them. An important line of our business, entirely separate from refrigeration, is building material, and our principal manufacture is that of lime, and one of the materials we

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make is a hydrate of lime, which we call "Limoid," a very light material. A large per cent. of it, something like 80 or 90, will pass two hundred mesh, and this material is of great benefit in preventing absorption in concrete. We all know that concrete will let water through. We have no doubt about that. Experiments that we have carried on, the results of which we will soon be able to publish, will show what a marked effect a small percentage of this lime in the concrete mixture will do to make it impervious to water.

I can remember one test. Under 40 pounds of water pressure, on a wall an inch thick, the opposite side did not get wet; you would wish nothing better than that. The experiments so far show that 20 per cent. of this "Limoid" in the cement, mixed in a satisfactorily proportioned concrete, rich enough, is practically impervious. It also has a tendency to increase the strength a little, although that is not my claim. I base my claim on its imperviousness.

We are going to build tanks in the near future on this principle. We will probably build one or two experimentally soon, in order to make ourselves acquainted with the difficulties, because our wooden tanks are beginning to leak now, and some of them are on their last legs. We have had them over seventeen years. We will, of course, reinforce them in some way, using some system of wire. If any members are interested in our material I will be pleased to take their names and report these tests to them; they will probably be of interest.

Edgar Penney—Is there any difficulty from cracking the concrete through expansion and contraction, or being subjected to a low temperature?

Irving Warner—As I have stated, we have had no experience in that matter, but the gentleman who spoke before me apparently had no trouble from that source, when it is properly done. It would take good workmanship, we know that. Now, the efficiency of reinforced concrete depends upon the fact that steel and concrete have the same coefficiency of expansion, practically. So far as that goes there is no danger from that source. It is merely a question of too intense a cold taking place on the surface, but we have our concrete sidewalks which are laid under practically identical circumstances.

Edgar Penney—They are chopped up.

Irving Warner—I know that. A tank is comparatively small compared with sidewalks.

J. S. Louis—In answer to Mr. Penney's question, the tank to

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which I refer was put in about four years ago, being subject, of course, to heat and cold, but it leaked a trifle when it was installed, and leaks no more than it did at that time, and I assume that the heat and the cold have not cracked it any more than they had originally.

John E. Starr—I might possibly add an instance in this line of experience with reinforced concrete in regard to its cracking. I built this year three large cold storage warehouses in which reinforced concrete was applied completely to the whole inside of the building; the columns and the floors were entirely reinforced concrete. One of those buildings, in St. Paul, was built in the summer; the weather was fairly warm, although it was finished in cold weather, so the concrete was set up under warm conditions and under cold conditions. The house was started in operation during the worst weather, the temperature running from 80° to 95°, and as is usual in cold storage works the building was behindhand, and we rushed the refrigeration and pulled the temperature of the building down in a very short time; in fact we had some of the rooms down to zero in five or six hours. That house was all under refrigeration during warm weather, with temperatures varying from 10° below zero to 35° above, and as far as the floors, which were about 6 inches thick, were concerned, and the girders and the columns, there was not a sign of a crack and there has not been a sign in more than six or seven months past.

The expansion and contraction necessarily were different in parts of the building on account of the temperatures existing. The floors were laid on top of the insulation, which consisted of an insulating block laid on the building floor proper, and on top of that was reinforced concrete flooring about 2½ inches thick. We expected that those floors would crack—I do not know exactly why. We did not expect the building would crack, but we certainly thought the floors would, and we expected that after they had finished cracking and the temperature was steady we could repair them by using a little chloride of calcium in the cement.

The floors did crack under the low temperature; they cracked quite a bit, but we had no difficulty in filling the cracks, using a small proportion of chloride of calcium in the cement set up under those low temperatures, and we had no further trouble. This may be some indication of what might be expected in a tank.

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* Associate Member.
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